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ABSTRACT

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning in cooperation with the Committee of Ontario Deans of Engineering has conducted a planning assessment for doctoral work in mechanical engineering. This report presents as overview of the recommendations for each of the assessments conducted in various areas of doctoral work. Following this overview, emphasis is placed on the assessment of mechanical engineering in relation to the number and quality of students, an analysis of mechanical engineering education at the doctoral level, and general observations. The section concerning the number and quality of students reviews the supply of students, foreign students, employment opportunities for graduates, student concern about career opportunities, and quotas on the number of students. Analysis of mechanical engineering education at the doctoral level reviews course requirements, doctoral theses, thesis work outside the university, part-time studies, coverage of mechanical engineering at the graduate level, strengths and weaknesses of graduate programs, and industrial research institutions. General observations discuss the minimum size of a group, metallurgy/material science. faculty age distribution, staff mobility, financial support for graduate work, and an overview of the Department of Mechanical Engineering at the University of Ottawa and the Institute of Aerospace Studies at the University of Toronto. (MJM)

ED 097828

Council of Ontario Universities
Conseil des Universités de l'Ontario

PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

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11. ENGINEERING 1974*

D. MECHANICAL ENGINEERING

Advisory Committee on Academic Planning
Ontario Council on Graduate Studies

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* The status of this report is given in Item 2 of the statement of principles, on page 1.

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D: Mechanical Engineering

TABLE OF CONTENTS

	Page
FOREWORD	i
REPORT AND RECOMMENDATIONS OF THE COUNCIL OF ONTARIO UNIVERSITIES - PART I	1-9
PART II	10-11
REPORT OF ADVISORY COMMITTEE ON ACADEMIC PLANNING	1-46
APPENDICES	
Appendix A: Report of Mechanical Engineering Consultants	A1-A38
Appendix B: Discipline Group Response	B1-B3
Appendix C: University Comments	C1-C34
Appendix D: Procedure of Planning Study and Terms of Reference	D1-D7
Appendix E: Discipline Group Membership	E1
Appendix F: Roles of ACAP and of Discipline Groups	F1-F4
Appendix G: Curricula Vitarum of the Consultants	G1-G4
Appendix H: Response of the Committee of Ontario Deans of Engineering	H1-H14

This report deals with a planning study of doctoral work in engineering, which was conducted in several portions corresponding to the various disciplines within engineering. The report is in six volumes. Volume A deals with chemical engineering, B with electrical engineering, C with metallurgical and materials engineering, D with mechanical engineering, E with industrial engineering, and F with civil engineering. Each volume contains the COU and ACAP reports for engineering as a whole together with the consultants' report and other material appropriate to one of the disciplines. The COU report will be in three parts: Part I dealing with recommendations approved in June 1974 and dealing with most of the fields, Part II approved in September 1974 and dealing with mechanical and industrial engineering, and Part III to appear later dealing with civil engineering. This volume printed in the fall of 1974 contains Parts I and II.

FOREWORD

As a consequence of a study of engineering education in Ontario (described in more detail in the subsequent ACAP report) the Council of Ontario Universities called for a planning assessment of PhD programmes in engineering to be carried out by ACAP in cooperation with CODE.

The Advisory Committee on Academic Planning (ACAP), as presently constituted, was established by the Ontario Council on Graduate Studies at the request of the Council of Ontario Universities in January, 1971. The Advisory Committee's terms of reference were directed broadly toward the effective planning and rationalization of long-term graduate development in Ontario's universities both at the level of individual disciplines and at a more general level. The Advisory Committee's activities are based on the premise that graduate work is the one area of university activity in which specialization among universities, cooperative arrangements and comprehensive planning are most necessary.

The disciplinary planning process involves a discipline group composed of one representative from each university with an interest in graduate work in the planning area. In the case of engineering, CODE was also involved in a way described in the ACAP report. The discipline group assists in defining the precise academic boundaries of each study, and prepares a commentary on the consultants' report.

The final decision on consultants for the planning study is made by ACAP. The consultants are requested to make recommendations on programmes to be offered in Ontario, desirable and/or likely enrolments, the division of responsibility for programmes among universities, and the desirable extent of collaboration with related disciplines.

While the consultants' report is the single largest element in the final report on the planning study, ACAP considers the statement of each university's forward plans to be most significant. These forward plans are usually outlined prior to the planning study, and are used as a basis for comments from the universities concerned on the consultants' report.

On receipt of the consultants' report, and comments on it from the disicpline group and the universities, ACAP begins work on its own recommendations for submission directly to the Council of Ontario Universities. COU considers the input from all sources, and prepares the position of the Ontario university community.

The following report is one of a series of disciplinary planning studies carried out by the Advisory Committee on Academic Planning and to be published by the Council of Ontario Universities. The emphasis of the report is on forward planning, and it is hoped that the implementation of COU's recommendations will help to ensure the more ordered growth and development of graduate studies in Ontario's universities.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Doctoral Studies in Engineering - Part I

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning, in cooperation with the Committee of Ontario Deans of Engineering, has conducted a planning assessment for doctoral work in engineering. This arose from the need to re-examine the recommendations concerning PhD work which appeared in Ring of Iron. The background to the study, the procedures followed and the planning techniques used are described in the ACAP report and are not repeated here. The resultant report from ACAP is attached together with the consultants' reports, the comments by the discipline groups, the comments of the individual universities, and the comments of CODE. It is important for the reader to read the attachments in order to understand the recommendations in this Report from COU. COU will issue subsequent parts to this report dealing with mechanical, industrial and civil engineering.

The Council received the ACAP report and supporting documentation on April 11, 1974. The content of the ACAP document was debated on April 11, on May 3, and on June 7, 1974. As a result of these discussions this Report and Recommendations was prepared and approved by the Council on June 7, 1974. The report is addressed to the Ontario Council on University Affairs and the universities of Ontario.

The following principles have been adopted and will apply to this and all other COU Reports arising out of assessments.

1. Discipline assessments by ACAP should form the basis for planning by the universities of their development of graduate studies, particularly PhD programmes. On the basis of these assessments, COU should make its own recommendations on currently embargoed programmes. Each university must retain the freedom and responsibility to plan and implement its own academic development. However, the universities in embarking on a cooperative planning process have signalled their intentions of cooperating with the COU recommendations.

2. Universities generally plan their emphases in graduate study on the bases of related departments, not of single departments. Initially the sequential nature of the discipline planning assessments makes this difficult. However, by the summer of 1974 there will have been assessments of most of the social sciences, all of the physical sciences, engineering doctoral work, and a number of professional areas. On the information and recommendations then available, each university should be able to make decisions concerning its support of graduate programmes in these areas. Amendments to university responses to the individual discipline planning assessments may then be made in the wider context of a group of related disciplines and amendments to COU's original Reports on an individual discipline may be required.

3. The first concern in planning is to review the quality of graduate opportunities and of students in Ontario universities and to make judgements about how to proceed or not proceed based on quality considerations. The procedures have made use of highly qualified independent consultants who have no direct interest in the universities in Ontario. Accordingly, COU feels bound to accept their judgements about quality where they are stated clearly unless unconvinced that their conclusions about quality are consistent with their evidence. COU's recommendations in the case of programmes which are of unsatisfactory or questionable quality will call for discontinuation or the carrying out of an appraisal, if the continuation of the programme is not crucial to the province's offerings. In some cases, however, there may be a particular need for the programme and the appropriate recommendation will be to strengthen it, with an appraisal following that action. It is also possible that if there were found to be too large a number of broadly-based programmes there could be a recommendation to discontinue the weakest; in this case, an appraisal for a more limited programme might be relevant.

4. A second consideration is the scope of opportunities for graduate work in the discipline. Do the Ontario programmes together offer a satisfactory coverage of the main divisions of the discipline?

5. Numbers of students to be planned for will depend on the likely number of applicants of high quality and in some cases may relate to an estimate of society's needs. Such estimates may be reasonably reliable in some cases and not in others. If the plans of the universities appear to be consistent with the likely number of well-qualified applicants and there is either no satisfactory basis for estimating needs or there is no inconsistency between a reasonable estimate of need and the universities' plans, then COU will take note of the facts without making recommendations on the subject of numbers.

   If the numbers being planned for by the universities are grossly out of line with the anticipated total of well-qualified students, or a reliable estimate of needs, COU will make appropriate corrective recommendations. Depending on the circumstances, these may call for a change in the total numbers to be planned for and indications of which institutions should increase, decrease, or discontinue. The recommendations in serious cases may need to specify departmental figures for each university for a time. If the numbers being planned for are insufficient, the recommendations may call for expansion, or new programmes, and may have implications for both operating and capital costs.

   Unless there are exceptional circumstances, the recommendations concerning enrolment will not call for a university to refuse admission to any well-qualified student who wishes to work in a field in which that university offers a programme and in which it has the capacity to accommodate the student.

6. The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design.

7. Universities will be expected to notify COU if they intend to depart from the COU Report in any way which they believe might have a significant bearing on the provincial plan.

8. Appraisals arising as the result of assessments are to be based on the standards but not necessarily the scope of the acceptable programmes in the province.

General observations concerning engineering doctoral work

1. Ontario is unlikely to over-produce engineering PhD's in the next five years. However, the student body contains too large a proportion of non-Canadians. Qualified Canadians should be encouraged to seek the engineering PhD.

2. Doctoral students should be selected on the basis of high academic standing and research potential.

3. "Inbreeding" is a problem, with many students obtaining three degrees from one university.

4. Faculty members, whether or not engaged with doctoral students, should have the facilities and opportunities to engage in research and in work with industry.

5. The scope for inter-university and university-industry cooperation is considerable and should be exploited.

6. The quality and state of development of the Ontario doctoral programmes are variable. Some are very good and have gained international recognition.

7. Some universities are organizing (or reorganizing) doctoral study on a division of specialization other than that provided by the "traditional" engineering departments. In two of the smaller faculties this is a central factor in the planning, but increasing cross-departmental activity is also in evidence elsewhere.

Actions by COU

1. COU has abandoned a planning number of 450 doctoral students and advises the universities to plan on the assumption that the doctoral enrolment will remain roughly constant for the next five years. Although there is a need for engineers with doctorates in Ontario, graduate student enrolment will level off due to a lack of top quality students. Canadians must be attracted in increasing numbers in order to maintain enrolment at the present level.

2. COU requests that CODE report annually to COU on enrolment and employment opportunities.

3. COU requests that ACAP arrange for each engineering discipline group:
   (1) to monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students (to ACAP for transmission to COU);

   (2) to report annually to ACAP on the universities previously attended by the newly admitted graduate students of each department.

4. COU requests CODE, after consultation with the discipline groups, to develop proposals for collective methods of making information on graduate work in all Ontario universities readily available to the engineering students, and to inform ACAP of the action taken.

5. COU requests OCGS to examine existing university guidelines on part-time doctoral work and its supervision.

6. COU request that ACAP arrange for an annual report to OCGS from each university on the time taken for each graduating student to complete his doctoral studies.

7. COU requests ACAP to examine the available documentation on civil engineering, to reach its own judgements on the basis for a report, after soliciting assistance from the discipline group and the universities, and to prepare its report to COU containing recommendations for the future of civil engineering doctoral work. This should be submitted by December 31, 1974.

8. COU requests that ACAP arrange for the metallurgical and materials engineering discipline group to present a report to ACAP on university actions taken to correct identified weakness in certain fields of study.

Recommendations

It is recommended that:

1. Universities, CODE and discipline groups take steps to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

2. The universities attempt to maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

3. The universities, the provincial government, and granting agencies examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined.

4. All doctoral thesis examining committees have an examiner external to the university.

5. At present, there not be any specific engineering doctoral part-time programmes but rather that part-time or non-resident doctoral work be done by individual arrangement. Experimentation in methods of carrying on part-time work is to be encouraged and might lead in future to the creation of specific part-time programmes. It is also recommended that the research topic of any student accepted on a part-time basis be in a field in which the professors in the department have expertise.

University Recommendations

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

It is recommended that:

6. The University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. If a favourable appraisal is not obtained by the end of October, 1976, admission of new students should then be suspended.

7. The University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained.

8. The involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the university begin doctoral work in agricultural engineering at a time in accordance with the university's plans, subject to normal appraisal procedures.

Chemical Engineering

This section deals with doctoral work in chemical engineering at McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

9. The departments consider grouping their research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

10. McMaster University continue its doctoral work in chemical engineering according to its plans.

11. The University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

12. Queen's University re-evaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the university considers appropriate. If a favourable appraisal has not been received by October, 1976, enrolment of new students then be suspended.

13. The University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to the desirable mobility of its bachelor's graduates for graduate work elsewhere and to the desirability of grouping of research areas. The University of Toronto is requested to report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

14. The University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

The consultants' report is unfortunately inadequate for planning purposes.

It is recommended that:

15. The embargo on the funding of any new programmes in civil engineering continue until COU has accepted a report from ACAP dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted by ACAP by December 31, 1974.

Electrical Engineering

This section deals with doctoral work in electrical engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

16. The discipline group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and

make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

17. Carleton University continue its doctoral work in electrical engineering according to its plans.

18. McMaster University continue its doctoral work in electrical engineering according to its plans.

19. The University of Ottawa plan the reorganization of its doctoral programme in electrical engineering and put forward the programme for appraisal. If a favourable appraisal has not been obtained by the end of the fall term 1976, admission of new students should cease. In the meantime, enrolment of new students should be restricted to the digital communications systems and large-scale systems fields.

20. Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields should be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

21. The University of Toronto continue its doctoral work in electrical engineering according to its plans.

22. The University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Metallurgical and Materials Engineering

This section deals with doctoral work in metallurgical and materials engineering at McMaster, Queen's, Toronto and Waterloo.

It is recommended that:

23. The universities take steps to increase the activity in the ceramics, glasses, and polymer fields of study in the province.

24. McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and make a report to COU through ACAP in the fall of 1975 on the following suggestions for improvement:

    a) recruitment of students with physics and chemistry backgrounds
    b) strengthening of the extractive metallurgy faculty
    c) collaboration with the University of Toronto

25. Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors from other departments. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish

to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

26. The University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto consider broadening the programmes and it is requested that the university report to COU through ACAP by September, 1975, on any progress made in this direction.

27. The University of Waterloo continue its doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

It is recommended that:

28. Queen's University continue its doctoral work in accordance with its plans.

General

It is recommended that:

29. In view of the acceptance of these recommendations by the Council of Ontario Universities and the completion of Part I of this planning assessment, the Ontario Council on University Affairs request the Minister to remove the embargo on doctoral work in Engineering (except for Mechanical, Industrial and Civil Engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo), in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until, for each discipline, a planning study has been conducted.

Notes concerning the recommendations

Re: Recommendations 1, 2, and 3

The background to these important recommendations appears on pages 13 and 14 of the ACAP Report.

Re: Recommendation 7

Presumably the programmes submitted for appraisal will be the three divisional programmes which are replacing the departmental programmes.

Re: Recommendation 16

Other engineering discipline groups may also find this a valuable suggestion.

Re: Recommendation 19

This differs from the recommendation in the ACAP Report because the University subsequently decided to carry out a re-assessment of the future direction of the department.

Re: Recommendation 25

Queen's has reported to COU its intention to enlarge its programme in extractive metallurgy.

June 7, 1974.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Doctoral Studies in Engineering - Part II

As Part I of this report indicated it would, this part deals with mechanical engineering and industrial engineering and systems design. Civil engineering will be dealt with in Part III.

The ACAP reports on mechanical and industrial engineering were debated by COU on June 7, 1974. As a result of these discussions, Part II of the Report and Recommendations was prepared and approved by Council on September 6, 1974.

The principles, general observations, actions by COU and recommendations 1 - 5 given in Part I apply generally and therefore have application to mechanical and industrial engineering. Similarly Recommendations 6,7 and 8 deal with doctoral work in engineering at Western Ontario, Windsor and Guelph, and, although the consultants' reports in mechanical and industrial engineering will be of value to these universities, no recommendations for them follow.

Mechanical Engineering

This section deals with doctoral work in mechanical engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

29. Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

30. If the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to the need for the department to have suitable industrial and research experience before applying for appraisal.

31. The University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. The University should consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

32. The University of Waterloo continue its doctoral programme in mechanical engineering. The University should consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

Industrial Engineering and Systems Design

This section deals with industrial engineering at Toronto and systems design at Waterloo.

It is recommended that:

33. The University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

34. The University of Waterloo continue its doctoral programme in systems design.

Notes: Re Recommendation 33

The University of Toronto is advised to expect about the same enrolment in doctoral work in industrial engineering as it now has, at least until such time as some new field of specialization may be approved.

Re Recommendation 34

The University of Waterloo is advised to give careful attention to the consultants' recommendations for strengthening its systems design doctoral programme before allowing the enrolment to grow.

August 27, 1974.

ADVISORY COMMITTEE ON ACADEMIC PLANNING

ONTARIO COUNCIL ON GRADUATE STUDIES

REPORT TO THE COUNCIL OF ONTARIO UNIVERSITIES
ON
ENGINEERING DOCTORAL PLANNING ASSESSMENTS

JUNE 7, 1974

TABLE OF CONTENTS

		Page
I	Recommendations	1
II	Background and Procedure	8
III	General Recommendations	13
IV	University Recommendations	20
	- University of Western Ontario	20
	- University of Windsor	22
	- University of Guelph	24
V	Chemical Engineering	25
VI	Civil Engineering	28
VII	Electrical Engineering	36
VIII	Mechanical Engineering	38
IX	Metallurgical and Materials Engineering	41
X	Mining Engineering	44
XI	Industrial Engineering and Systems Design	45

For each planning assessment (Chemical, Civil, Electrical, Mechanical, Metallurgical, and Industrial) there are appended:

- Appendix A - Consultants' Report
- Appendix B - Discipline Group Response
- Appendix C - University Comments
- Appendix D - Procedure of Planning Study and Terms of Reference
- Appendix E - Discipline Group Membership
- Appendix F - Roles of ACAP and of Discipline Groups
- Appendix G - Curricula Vitarum of the Consultants
- Appendix H - CODE Response

I. RECOMMENDATIONS

General Recommendations

C1

It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

C6

It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

C7

It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

University Recommendations

C10

It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained by that date.

C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

Chemical Engineering

C13

It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

C14

It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

C15

It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

C16

It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

C17

It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

C18

It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

C19

It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

Electrical Engineering

C20

It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

C21

It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

C22

It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

C23

It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

C24

It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

C25

It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

C26

It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Mechanical Engineering

C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

C30

It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

Metallurgical and Materials Engineering

C31

It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these recommendations.

C32

It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:

a. recruitment of students with physics and chemistry backgrounds

b. strengthening of the extractive metallurgy faculty

c. collaboration with Toronto.

C33

It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

C34

It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975, on any progress made in this direction.

C35

It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

C36

It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

Industrial Engineering and Systems Design

C37

It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

C38

It is recommended that the University of Waterloo continue its doctoral programme in systems design.

II. BACKGROUND AND PROCEDURE

In June, 1968, the Committee of Presidents of the Universities of Ontario, after a meeting with the chairman of the Committee on University Affairs, decided that a comprehensive review of engineering education in Ontario should be undertaken. The Committee of Ontario Deans of Engineering (CODE) was requested to draw up plans for such a study, and this proposal was approved by the Committee of Presidents on November 15, 1968. The objective was to create a master plan which could be used as a guide for rational growth of engineering education during the 1970's. Such a plan should endeavour to provide for the highest attainable quality, the best use of resources, opportunity for innovation, and maximum freedom of choice for students.

This study culminated in the report Ring of Iron prepared by a commission chaired by Philip Lapp.

The report was received by the Committee of Presidents in January, 1971. A process of review of the report's recommendations was established, CODE prepared a brief based on statements of views submitted by each university concerned and by each Faculty of Engineering. Briefs were prepared also by the Ontario Council on Graduate Studies (OCGS) and the Association of Professional Engineers of Ontario. On October 5, 1971, the Council of Ontario Universities (COU) considered Ring of Iron and the briefs and prepared a statement of recommendations to the universities and to CUA.

COU accepted a number of the Lapp recommendations without change, others with amendments and rejected some. Broadly speaking, the recommendations to do with undergraduate matters were accepted or modified slightly. The graduate area of the report was more controversial, but here also some recommendations were accepted. The most significant of the recommendations concerning graduate study, as approved by COU, are:

> "The criteria of acceptability of graduate degrees in engineering should be recast in order that a thesis based on design or systems synthesis may be suitably assessed. This could involve the establishment of a new degree at the doctorate level."

> "Both universities and industries should recognize joint appointments as part of the career structure of their senior staff; these appointments should be increased as far as possible..... By this we understand a system of part-time appointments."

> "Over the next two years the estimated graduate enrolment of 2,000 full-time equivalent students for 1970-71 be reduced by 17%, after which graduate enrolment should be limited to a number equal to the previous year's bachelor graduations. The enrolment figure applies to the engineering departments as identifed in Ring of Iron".

> "The recommendation that the number of PhD students enrolled be reduced to 450 per year is fully supported by all groups including COU. However, COU, along with CODE and OCGS, recommends that the figure of 450 be the target for 1974-75, rather than for 1973-74, for reasons related to avoiding large fluctuations in enrolment as explained in the OCGS critique."
>
> "The Lapp report recommends specific numbers of PhD enrollees for each of the universities including discontinuance of the PhD enrolment in certain universities. COU feels that the reasons for the numbers chosen or for the elimination of certain doctorate programmes are not fully documented in the Lapp report. COU also agrees with CODE and OCGS that attention must be given to the numbers of doctorate enrollees by discipline as well as by university. For these reasons COU recommends that for the year 1972-73 doctorate enrolment be reduced in each university below the projected figure for 1971-72 by a pro rata percentage in order to provide 612 doctoral candidates (the number required to achieve the target of 450 in 1974-75). Preliminary acceptance of the OCGS method for reducing PhD enrolment (by limiting new PhD enrolments to achieve a total system number of 450 by 1974-75) is based on plans for discipline planning assessments respecting PhD programs to be initiated immediately and completed as rapidly as possible. Such assessments will be carried out by ACAP in cooperation with CODE; they are to incorporate capability, demand and quality correlates, and are to be used to provide specific recommendations on changes for the total PhD enrolment, and for the division of the enrolment amongst universities and amongst disciplines. The assessments are to incorporate a review of the effects of the pro rata reductions in 1972-73, and to recommend a mechanism for continuing review of PhD enrolments."

On receipt of this instruction from COU, ACAP and CODE established a liasion committee (Ayers, Dillon, Ham, Johnson, Shemilt, McIntosh, Preston) which drafted procedures for the assessments. It may be noted that the committee considered a model in which the assessments were based, not on the five traditional departments found in engineering faculties, but rather on interdepartmental areas of research; the practical difficulties of conducting the assessments led the committee to recommend the five-fold subdivision actually used.

The procedure developed in this way was approved by ACAP on March 17, 1972, and by COU on April 7. The procedure (except for minor data amendments) is that in Appendix D to this report. In writing to indicate its approval CODE expressed their understanding that two objectives would be met:

> "1. To provide a rational basis for doctoral work in engineering and for confirming or modifying the limitation on enrolment suggested by Lapp.
>
> 2. To conduct a really effective assessment of the quality of our current doctoral programmes."

CODE went on to emphasize the need of adequate resources to obtain the best consultants.

In order to begin the planning assessments, the ACAP/CODE liasion committee called a meeting of members of the five Discipline Groups (Chemical, Civil, Electrical, Mechanical, and Metallurgical Engineering). This meeting on April 12, 1972, indicated a good deal of faculty resistance to the conduct of the planning assessments and uneasiness about some perceptions of some aspects of the approved procedures. This resulted in a delay in mounting the assessment. CODE suggested a Coordinating Task Force, consisting of two members of CODE, the chairman of each Discipline Group, and a member of ACAP could review the procedures. ACAP advised COU to agree to this request and the COU executive did so on June 9, 1972. This Task Force held meetings on June 29, July 27, September 1, September 25, November 29, 1972 and March 19, 1973. It suggested two slight additions to the procedures as approved earlier by COU. These were approved by COU on September 25, 1972. The Task Force also produced a document clarifying some aspects of the procedure in detail, and a statement of some educational philosophies concerning doctoral study. These documents are referred to in the terms of reference of the consultants. The Task Force also advised ACAP (and so did universities) on how to take into account for planning purposes those doctoral programmes in Faculties of Engineering which did not fall obviously into the fields covered by one of the five consulting teams. It was eventually decided that:

a) both the metallurgy and the mechanical engineering consultants would be asked to consider the metallurgical work within the Department of Mechanical Engineering at Waterloo

b) no advice from external consultants would be sought on the doctoral programme in mining engineering at Queen's

c) a small-scale "planning assessment" involving two consultants would be carried out in industrial engineering and systems design

d) in view of the fact that all current doctoral students at Guelph are in hydrology and that the field of agricultural engineering is also proposed, the civil engineering consultants would be asked to consider the Guelph doctoral work, with the understanding that if they so wished ACAP would facilitate a consultation for them with someone in a department of agricultural engineering

e) the mechanical engineering consultants be asked to consider the doctoral work at the University of Toronto Institute of Aerospace Studies and in aeronautical engineering at Carleton, with the request that they consult also with another of the ACAP consultants (on the Electrical Engineering team) who had expertise in some of the UTIAS work outside mechanical engineering and also with an aerospace specialist

f) advice on the future plans of the Department of Management Science at Waterloo would be sought from the consultants in the planning assessment in Administration, Business and Management Science, with a comment also provided by the consultants on industrial engineering.

g) no special arrangements were needed in connection with biomedical engineering at Toronto since the corresponding institute has no graduate programme of its own, and the future doctoral plans are covered in the statements from each of the associated departments.

Item f will be dealt with in a later report. The remainder are covered in this report. The mechanical engineering consultants informed ACAP that they did not require the assistance suggested in item e.

In October, 1972, CODE proposed that a study be carried out, under the aegis of the newly established Canadian Engineering Manpower Council, and with financial support from a number of agencies, in order to make recommendations about "supply and demand" for engineering doctorates. This would be expected to be of great value to the planning assessments. ACAP agreed to this suggestion, provided funds towards the costs, and incorporated reference to the study into the instructions for the consultants. In the event, the study proved rather disappointing; it is discussed later in this report.

As a result of suggestions from the Discipline Groups and after receiving comments from the Coordinating Task Force and from CODE, ACAP agreed on consultants at its meetings of September 7-8, October 13 and December 18, 1972. The consultants who finally acted were:

Chemical Engineering:	Dean P. Grenier of Université Laval, Dean W. R. Marshall of the University of Wisconsin, Professor L. Yaffe of McGill University
Civil Engineering:	Professor W.W . Eckenfelder of Vanderbilt University Mr. B. V. Martin of Alan M. Voorhees and Associates Ltd., Professor G. G. Meyerhof of Nova Scotia Technical College, Dr. J. L. Boulet of Hydro-Quebec.
Electrical Engineering:	Professor A. D. Moore of the University of British Columbia, Professor M. E. Van Valkenberg of Princeton University, Dr. M. P. Bachynski of RCA Research Laboratories

Mechanical Engineering:	Professor H.W. Emmons of Harvard University, Dean G. Ford of the University of Alberta, Dr. R. D. Hiscocks of the National Research Council of Canada, Professor S.G. Mason of McGill University
Metallurgical Engineering:	Professor J.J. Jonas of McGill University, Professor T.B. King of the Massachusetts Institute of Technology, Professor W.S. Owen of Northwestern University and M.I.T., Dr. W.B. Lewis of Atomic Energy of Canada Ltd.

Brief curricula vitarum appear in Appendix G. In each case, the last named person played the role of a senior Canadian from outside the discipline.

The consultants held their first meetings at various dates in April and May, 1973 and in each case met with the appropriate Discipline Group, arranged the schedule of visits, discussed their character and had general discussion with the Discipline Group about the task before them. The visits took place in the two or three months following these meetings.

The consultant teams each submitted a draft report in September, which was the subject of oral discussion with the Discipline Group at a meeting within a few days of the receipt of the draft. Each consultant team then submitted its report. These reports were sent for comments to the universities, to the Discipline Groups and to CODE, each of which sent comments to ACAP at various dates in November, December and January.

A subcommittee of ACAP began consideration of the report to COU, before all the comments were in hand and continued its work through March, 1974, reporting regularly to ACAP and receiving instructions. Early in its meetings the committee identified some points on which further information and reactions were required. In particular, the need for fuller advice from the consultants. was felt in the cases of civil and mechanical engineering. Such further advice was sought, with results discussed in the relevant sections of this report. ACAP also thought some further information would be helpful in connection with three of the universities and arranged meetings with officials of these universities and members of ACAP.

This report is based on the consultants' reports, the data collected for the study, the universities' comments and supplementary material from some of them, the Discipline Groups' responses, and the other documentation referred to in the procedures and terms of reference. The report sets out recommendations for COU on doctoral work in engineering in Ontario for the next few years.

As is required, ACAP presents this report directly to COU. It has also been transmitted for information to OCGS, CODE, and the Discipline Groups.

III. GENERAL RECOMMENDATIONS

This section of the ACAP report contains recommendations that are of general concern to all of engineering. Some of these recommendations have been mentioned consistently in all the reports while others, although found in only one report, are applicable to all doctoral programmes.

Enrolment and Manpower Forecasts

In the summer of 1973, the Canadian Engineering Manpower Council released its report entitled Supply and Demand for Engineering Doctorates in Canada. This report was partly financed by ACAP and was given to all the consultant teams prior to their writing of their reports. It generally states that the supply of engineers in the next five years will exceed the demand.

A summary of the comments made by the engineering consultants concerning this report shows that they all independently disagree with the projections made in the CEMC report. They believe there has been no overproduction of PhDs to date and, in fact, there appears to be a shortage of metallurgical PhDs. Each team believes that the need for engineers will not decline, as predicted by CEMC but that the overall demand will continue and in actual fact, all but the civil engineering consultants believe it will increase.

ACAP had originally intended to publish a critique of the CEMC report. However, CODE in its repsonse to the engineering reports, Appendix H, has included a statement on this report covering all the points ACAP wished to make. ACAP's critique will not be reproduced, but we feel that the CEMC report is not an adequate basis for manpower planning in engineering. Since all the consultants agree that supply will not exceed demand but perhaps rather the reverse, the question of supply of qualified students must be studied. The main problem will be attracting Canadians into engineering graduate work. In 1972-73, of the 518 F.T. engineering PhDs, 28.6% were Canadian, 53.3% were landed immigrants and the remaining 18.1% were on student visas.

Changes in the immigration regulations make it harder to become a landed immigrant. Since one can no longer apply for landed immigrant status while in Canada, those that come on student visas will presumably return to their homelands. Coupled with this is another new regulation that a teaching assistantship is no longer classified as a job, thus making it harder to obtain landed immigrant status. Consequently, ACAP feels that the percentage of landed immigrants in graduate work will drop while the number of students visas will increase. Financial support for people on student visas is scarce. There are very few scholarships or bursaries open to them but in engineering they may be supported from contract funds. In any case, there will be funds for only a few. Although Canada has a role to play in providing advanced technical education for the underpriviledged countries of the world, this should be kept to a reasonable level and should not exceed 30% of engineering doctoral enrolments.

CODE, on page H-9 of its response, states that "unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline". There are suggestions that student stipends be increased. We remain unconvinced that stipends need be any higher in engineering than in any other field, but there is one exception and this is that people with substantial professional experience returning to graduate study should be supported at a higher level.

ACAP is inclined to agree with the University of Waterloo's comment, page C-29 in its response to the chemical engineering report, that the best way of attracting Canadian students is a "change in the general atmosphere surrounding doctoral work in engineering in this country and to convince the brightest young Canadian students that there are challenging opportunities for advanced work in Canadian industry". Increased dialogue with industry as well as up-to-date information on jobs available would make the employment picture brighter and more alluring to prospective Canadian graduate students especially if the number of industrial scholarships were increased and more interaction were seen to be taking place between industry and university.

This dialogue with industry is needed to ensure that more Canadians continue in graduate work. If industry indeed has a place for the master's or doctorate in engineering, more must be done to encourage good students to stay in university instead of taking a job after the bachelor's degree. Industry in its hiring policies can encourage this.

The chemical engineering consultants recommend that the universities should endeavour to develop entrepreneurship in students. They feel "this is a quality so badly needed at present in Canada".

It does not seem as though Ontario will overproduce engineering PhDs in the next five years. The question is rather whether there will be enough qualified students. In view of this possible shortage, the following recommendations are made by ACAP.

Recommendation C1

> It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

Recommendation C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

Recommendation C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

Recommendation C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

Admissions

ACAP does not support the view held by the electrical engineering consultants, namely that admitted doctoral candidates should have first class standing and proven research ability. Many students who graduate with high second class honours have become excellent research engineers. The usual minimum standard of the better departments is a high B and all the consultants agree that high standards of admissions prevail generally.

Recommendation C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

CODE agrees with ACAP on the annual post facto analysis of admission practices (page H-3). The chemical engineering consultants have suggested "that should it be found that students have been accepted who, in the opinion of the committee, do not fulfill the minimum requirements, the committee advise COU that a recommendation be made to the requisite authority suggesting no BIU be awarded for that student". ACAP does not feel this to be necessary at the present since regular reporting by the Discipline Group should exert considerable pressure if an institution repeatedly admits students of a low standard.

Undergraduate-Graduate Relationship

Some consultants assert that each department should provide all levels of study: bachelor's, master's and doctoral. Some go so far as to say that a doctoral programme in each department is essential. CODE, on the other hand, feels that what is important for a good undergraduate programme is research and professional activity by the faculty, and that this can be carried forward without graduate students, although at present the research activity is most easily carried on through graduate programmes (page H-3). ACAP agrees with the position stated by CODE and indeed applies it to all subjects, not only engineering, but with the comment that in many fields it is not difficult for a professor to be active in research without having graduate students. We would point out that the other position would imply that no department should exist unless it can operate an effective doctoral programme, a view which we find impossible to accept. The absence of sufficient research and professional activity by professors would raise questions about the quality of a department and hence of its undergraduate offerings, whether or not it offered doctoral work.

Thesis Quality

Recommendation C6

> It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

Since some of the consultants have made reference to the make-up of examining committees ACAP would wish to endorse this practice of including an external examiner.

Critical Size

We agree with CODE that there must be sufficient range of interaction for the student and that the judgement as to the presence of this interaction must include consideration of the involvement of persons outside the student's department and should include post-doctoral fellows and research associates as well as students. Although these planning assessments were vertical, as CODE suggests, each department was asked to state the extent of this interaction in its university. We agree that there is no *a priori* reason why a small school cannot provide as satisfactory an environment as can a large school. The question is not one of principle, but one of fact: does university A in fact provide the requisite environment for interaction for the average student in its department X?

Most of the consultants considered this question carefully and made specific comments but others provide no evidence that they examined the matter in any of the universities. While most agree that successful programmes can exist in small as well as large departments, the consultants still expect a wide range of courses to be offered. This in turn requires a certain number of students to make the courses economically feasible and academically stimulating.

Mobility of Students

The chemical engineering consultants are concerned about the lack of mobility of engineering students. They do not consider it a good educational experience to study for all three degrees, the bachelor's, the master's and the doctorate, at the same university. Such a programme leads to inbreeding and sameness and precludes any chance for the student to come in contact with different faculty, students, milieu and methods.

One sometimes hears a professor accept this in theory, but then say that in practice the student must not be prevented from going to the university of his choice. That view appears to us to be correct, provided the student's choice is made on sound academic grounds, based on good information of the opportunities that are available to him, and taking account, of course, of the undesirable aspects of remaining in one university.

Recommendation C7

> It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

Part-time Programmes

In 1972-73, 18% of the doctoral students studying engineering were doing so on a part-time basis. 65% of these students were Canadians and another 32.5% were landed immigrants. It would appear that these part-time programmes are being used by the profession to upgrade the skills and knowledge of its practising engineers.

The consultants seem divided on the issue of part-time programmes, some saying "such undertakings should be rarely encouraged" and others, "full encouragement should be given to part-time doctoral programmes." ACAP feels that there is a place for the part-time programme and that careful attention should be devoted to designing part-time programmes, bearing in mind the strengths of the departments. One of the dangers sometimes noted is that students become involved, under a part-time supervisor, in a project in an area in which the full-time staff has limited expertise; this is not recommended.

Recommendation C8

> It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

Cooperation

One of the main points that all the consultants agree upon is the need for increased cooperation both within and between universities. The chemical engineering consultants found a need for increased interaction between the engineers and the pure science faculties. Some of the other consultants felt the need for more communication and cooperation between the universities and industry and government. Lastly, more effective use could be made of the resources in the province if the universities themselves joined together in some form of cooperative endeavour. CODE endorses this last point quite strongly in its response, page H-4. Sharing of equipment, discipline meetings and an interchange of credits for graduate courses are a few of the methods listed by CODE that are to be encouraged on the way to making this cooperation a meaningful and workable venture. ACAP concurs with the statements made by the consultants and CODE and strongly supports their implementation.

ACAP intends to request that each Discipline Group report regularly to ACAP on interuniversity cooperative arrangements.

Faculty

Two sets of consultants found enough disquieting evidence in the engineering faculties of the province to suggest that the requirements for a faculty member, eligible to supervise graduate students, should be reviewed and enforced. ACAP takes no position on whether or not there should be a separate Graduate Faculty, but there must be a mechanism to ensure that only those faculty with proven research ability and productivity supervise graduate students.

Since this concern has been mentioned in other assessments, ACAP feels it is time that OCGS conduct a review of this area.

Time to Reach Degree

The electrical engineering consultants were concerned about the length of time taken to obtain the PhD. As they pointed out, the average student at one university took 13-20 months longer to complete his doctorate than his counterpart at another university. As a whole, they found the average time of study to be excessive.

Recommendation C9

> It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

IV. UNIVERSITY RECOMMENDATIONS

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

University of Western Ontario

The University of Western Ontario began to offer doctoral work in engineering in 1965. Since then, twenty PhDs in Engineering Science have been granted. From the beginning effort has been made to emphasise its interdisciplinary nature and there has been a limited number of areas in which the student may do his graduate training. At no point has a doctoral degree been given in the so called traditional fields of engineering.

There are seven main research areas in which a student may obtain a PhD in Engineering Science. They are 1. Geotechnical 2. Boundary Layer Wind Tunnel 3. Chemical and Biochemical Process Development and Design 4. Material Science 5. Systems 6. Applied Thermodynamics and 7. Applied Electrostatics. Environmental engineering aspects can be studied in all these research areas except Material Science.

Western's response to the collective engineering picture gives the 1973-74 enrolment as 29 F.T. and 15 P.T. doctoral students. In the additional data given to ACAP, 18 of the 37 current students' programme of study outlined were in the chemical engineering field, 8 were civil, 5 mechanical, and 3 each in electrical and material science.

The chemical engineering consultants have provided evidence of that programme's being of good quality. The systems research area depends heavily on chemical engineering. ACAP, therefore, concludes that the research areas Chemical and Biochemical Process Development and Design, and Systems are of satisfactory quality.

The metallurgical engineering consultants have recommended that the Material Science programme become a part of an interdisciplinary programme rather than an exclusively material science one. This was in part based on the fact that the group is small and spends most of its time teaching at the undergraduate level. They are "carrying a large programme for a group which is subcritical in size." From the additional material supplied by Western, there is little evidence of interdisciplinary activity for students who might be doing research in this area. ACAP concludes that this area should not be operating at the doctoral level.

The areas of mechanical engineering doctoral research work are subsumed under the main research area, Applied Thermodynamics. The consultants indicate that the doctoral research connected with heavy water is of good quality but they raise very serious questions about the doctoral work in acoustics. They feel this area should be restricted to work at the master's level.

The civil engineering consultants did not make comparative judgements, but from some of the phrases used to describe the Boundary Layer Wind Tunnel Laboratory such as "internationally known", ACAP has no reservations in recommending continuance of doctoral work in this research area, even though it appears to have little interaction with other groups. The civil engineering consultants told us nothing about the Geotechnical area and we, therefore, had difficulty in recommending a position to be taken with regard to this field.

The last research area, Applied Electrostatics, is the most difficult to assess. The electrical engineering consultants have recommended discontinuance of the doctoral programme. They feel the students are getting too narrow a training in electrical engineering. We observe, however, that the students are not considered to be studying for a PhD in electrical engineering, but rather for a general degree in engineering science. Although there are only a few faculty members in this area, they are internationally known. The main problem would, therefore, seem to be the extent to which the doctoral training in this area is of an interdisciplinary nature. From the data available to ACAP, we are unsure.

In the course of discussions with representatives of the University of Western Ontario, it became clear that the Faculty is involved in a thorough re-examination of its doctoral programme. It is committed to the concept of an engineering science PhD but is reconsidering the appropriate areas of research. While it is not entirely accepted by ACAP that all the activity is noticeably different from that in engineering departments elsewhere, we nevertheless believe that this intention of the Faculty should be encouraged. A corollary is that it must be very careful about the research areas in which it accepts PhD candidates; we have already commented on these and note the standard of quality seems variable.

These considerations have led us to formulate the following recommendation.

Recommendation C10

> It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

University of Windsor

Early in 1971, the Faculty of Applied Science at the University of Windsor began to examine the structure of graduate programmes within the Faculty in order to improve their operation, avoid needless and costly duplication of graduate course offerings and to attempt to create a greater cross-fertilization of research by involving faculty members from different engineering departments in various facets of a larger research plan. This examination led to the recommendation that Graduate Studies be operated on a divisional basis, with the seven undergraduate departments being consolidated under three graduate divisions, namely Engineering Process Design, Structures and Systems. The three divisions would each elect a chairman who would decide on course offerings and enrolment levels. The three chairmen, one elected member from each division, one graduate student and the Dean of Applied Science form a Coordinating Committee to oversee and coordinate the wishes of the Divisions. This plan was approved in Spring 1972 and is now being implemented.

Some of the traditional departments such as chemical and electrical fall completely in one division. All the rest are split between two as can be seen in the attached Table 1.

There are nine identifiable research areas, each of which have participating faculty from at least two of the old departments and these nine areas are in turn divided fairly equally among the three divisions.

The degrees awarded will retain the old titles, for example, a PhD in Chemical Engineering, but the interaction of the individual student with others in the Faculty will be greatly enhanced. Depending on his research topic, the student might take as many as half his courses from professors in other 'departments'.

The consultants' comments concerning Windsor vary, but a number of their reports imply some doubt or uncertainty concerning the relevant departmental programme, either with respect to the situation at the time of their visit, or in connection with its future direction. The chemical engineering consultants suggest that Windsor be reviewed in greater depth. The metallurgical engineering consultants recommend the integration of engineering materials faculty in the new divisional system. The mechanical engineering consultants call for more emphasis on master's work. In the case of electrical engineering the consultants indicate that good work is now being done in doctoral education in two fields, agree with the present plans for no significant growth in enrolment and for no expansion of fields, and go on to recommend a review after five years.

In view of these considerations ACAP feels the University of Windsor should be given time to produce a viable interdisciplinary system of doctoral engineering studies before that system is brought forward for appraisal. This appraisal would determine the level of quality in the new divisional system and whether or not significant interaction has been achieved between the staff and students of the various departments.

Table I

Organization of Engineering Doctoral Work at the University of Windsor

a. % of Department Involvement in each Division

Department	Engineering Process Design	Structures	Systems
Chemical	100%		
Civil	40%	60%	
Electrical			100%
Engineering Materials	50%	50%	
Industrial	10%		90%
Mechanical	60%	40%	

b. Departmental Research Interests

Research Interests Department	Structures	Electric Power	Thermofluids	Systems and Signals	Human Factors	Mechanical Metallurgy	Physical Metallurgy	Water and Air Quality	Vibration and Noise
Chemical			x					x	
Civil	x		x			x		x	x
Electrical		x		x					
Engineering Materials	x		x			x	x		
Industrial				x	x	x		x	x
Mechanical	x		x	x	x	x			x

Recommendation C11

> It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977 if a favourable appraisal has not been obtained by that date.

University of Guelph

The University of Guelph has for sometime offered an interdepartmental PhD programme in Hydrology in which its Engineering School plays a part. It also plans to develop doctoral work in agricultural engineering, which it already offers at the master's level. There are no other programmes in agricultural engineering in the province.

The matter of the interdepartmental programme would appear not to be central to this assessment. It would not be inappropriate for the Civil Engineering Discipline Group to keep this programme in mind when carrying out the study called for in Recommendation C19. Nevertheless, it seems unnecessary to await the Discipline Group report to make the recommendation which follows.*

From the planning viewpoint, there seems no reason to do other than accept the University's intention to begin doctoral work in agricultural engineering, whenever it feels the time is ripe and the proposal has passed appraisal.

Recommendation C12

> It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

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* It may be noted that COU did not accept Recommendation C19.

V. CHEMICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the chemical engineering consultants' report. There will be no reference made to Western or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C13

> It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

Recommendation C14

> It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

McMaster specializes in process simulation, waste-water treatment, polymer engineering, chemical reaction engineering and catalysis, and transport and separation processes, with stronger emphasis on the first two areas. The consultants feel that McMaster's goals for the future are "realistic" and appear to be "achievable and productive".

Recommendation C15

> It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

The University of Ottawa specializes in three main areas including thermodynamics and transport properties; kinetics, catalysis and reactor engineering; and transport processes. There has recently been a shift towards a greater environmental emphasis. The consultants encouraged Ottawa to keep up with changes in the areas of research and graduate teaching and move into these new areas whenever possible.

Recommendation C16

> It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

Queen's University specializes in the following five doctoral research areas: biochemical and environment engineering, chemical kinetics and reactor design, process control and simulation, thermodynamics, and transport phenomena. These areas cover most of chemical engineering making a rather uniform distribution of effort. The publication records of only two professors are very good, all the rest being average or low. This raises questions as to the activities of the faculty since their connections with professional and scientific societies can be described as "only mildly active". The consultants feel alarm at the number of Queen's bachelor's graduates who undertake graduate work at the same institution.

On the optimistic side, the consultants note that "the very excellent development planning and programme forecasting suggests that the department's goals and future research activities will be relevant and responsive to the prevailing needs of the province".

ACAP suggests that Queen's might consider strengthening its present faculty, or alternatively, it might consider consolidating its existing wide scope of research areas. As to inbreeding of students, ACAP draws Queen's attention to Recommendation C7.

Recommendation C17

> It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975 on action taken in regard to this Recommendation.

The University of Toronto lists eight areas of specialization, all of which show a rather uniform distribution of faculty effort. The exception is a marked emphasis on applied chemistry. The consultants would like to see an effort to group the staff in given areas of research instead of the present policy of allowing a staff member "to select his own path". The consultants did not find Toronto's statement on its plans particularly helpful and they offered no comment on it, other than to say that "it is doubtful whether any increase above the present enrolment would be beneficial to these new students or to the student body as a whole". The University of Toronto should also encourage mobility of its graduates to the benefit of other departments and of the students alike.

Recommendation C18

> It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

The University of Waterloo has grouped its research activity into five areas including biochemical and food engineering, extractive and process metallurgy, polymer science and engineering, mathematical analysis and control, and transport processes and kinetics. The scope is wide, covering a large part of chemical engineering but, there are defined groups to coordinate the programmes. Although the consultants considered the statement of goals and objectives "less positive and definitive" than others, they were pleased to note Waterloo's intention "to ensure research activities by the use of more post-doctoral fellows and hired research assistants (non-degree candidates) if this should become necessary".

VI. CIVIL ENGINEERING

The report of the civil engineering consultants contains a number of important recommendations of a general character.

Their discussion of the manpower situation supports our Recommendation C1. They suggest that it would be wise to expect rather fewer students than the totality of the stated university plans. Considering the uncertainty of the manpower analysis and the size of the numbers involved, ACAP does not feel it desirable to formulate any recommendations about individual enrolment. ACAP does advise each university to consider the likelihood that the doctoral enrolment in civil engineering may fall still further unless the fraction of Canadian students increases substantially from its present level of about 25%.

Their comments that the "study of a civil engineering speciality in depth necessitates increasingly...some graduate work", reinforces our Recommendation C2 concerning publicizing the value of graduate work.

They argue for more part-time work and closer liaison with industrial and governmental laboratories. Recommendations C2 and C8 touch on this point.

The consultants on pages A-18 and A-35 express their concern that students tend to remain for graduate study at their undergraduate universities, often being unaware of offerings elsewhere. We make recommendations on this problem in Recommendation C7.

The consultants perceive a need for "more consistent requirements of acceptance....between universities". Although we do not recommend the particular remedy they suggest we do make Recommendation C4 in this connection.

On matters specific to civil engineering, the consultants stress the need for more emphasis on fields other than structures. They call for less stress on "traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation". They suggest that "change of programme emphasis in civil engineering (will) lead to some growth in faculty when generally universities are expecting a fairly static period". On pages A-49 and A-50, they quantify this shift by asking for a 20% reduction in doctoral enrolment in structures (i.e. a drop of about 15 students) together with a corresponding increase, roughly equally in transportation and water resources. Perhaps rather surprisingly they then suggest that no university should offer a new field at the doctoral level. (On page A-52 they also suggest that no university reduce "the range of its doctoral programmes" but on page A-51 they add "unless that university desires otherwise".)

The consequence of this stance, based on pages A-25 to A-29, is summarized in Table 2.

Table 2

CIVIL ENGINEERING

Possible Consequences of the Consultants' Recommendations on Enrolment and Field Emphasis

Universities	Fields				Order of Magnitude of Enrolment
	Geo-technical	Structures	Water Resources	Transportation	
Carleton	S	R	-	I	6
McMaster	-	S	I	-	10
Ottawa	S	R	I	-	17
Queen's	S	R	-	-	8
Toronto	S	R	I	I	25
Waterloo	S	S	I	I	30

LEGEND: R - reduce enrolment
S - static enrolment
I - increase enrolment

NOTE: Guelph, Western Ontario and Windsor are not included in the chart as they are dealt with elsewhere. (See section on University Recommendations.)

There are difficulties in accepting these recommendations. For example, if one asks what the shifts of enrolment from structures would be, to total around 15, one comes up with something like: Carleton 2, McMaster 0, Ottawa 3, Queen's 2, Toronto 4, Waterloo 4. Looking then at transportation one finds doctoral programmes at Carleton, Toronto, and Waterloo which might increase by 2 or 3 at each place. One has to ask if this is the best way to develop more high quality doctoral work. Would it be a better strategy to encourage Carleton, for example, to build a somewhat larger group than 3 or 4 students? There is another concern. Are all the transportation groups of equal promise as places to do doctoral work? If not, should some be strengthened more than others? If we really believe in penny-packet enrolments, could a fourth university perhaps enter this field? The consultants' report provides no satisfactory discussion of these questions to justify its proposals.

Equally unsatisfactory, and perhaps more basically disturbing, is the consultants' failure to give any discussion whatsoever (with three small exceptions) of the facts and reasoning which led them to conclude that all existing programmes are satisfactory. This may be so, but the rationale is far from clear. As the appended correspondence (Appendix 1 to this section) shows, the consultants decline to discharge their terms of reference, in particular C3c and the paragraph following C3d. (See Appendix D).

In particular, although the matter of critical academic enrolment size is discussed in generally acceptable terms, in that the proposition is stated that there is no a priori reason to assume a small school cannot provide as satisfactory an environment for a PhD student as a big school, the consultants neither state the characteristics of such an environment nor do they make any effort to show that it exists in the several small programmes they examined. Although it is no doubt possible to make the justification in several cases, nevertheless a question must still loom unsettled as to the academic strength (from the potential students' viewpoint) of several of the programmes, namely Carleton, Guelph, McMaster, and perhaps Ottawa and Queen's. (None has been appraised.) Of course the consultants' report, due to the lack of rationale in it, gives no reason to suppose that the larger departments are necessarily of suitable quality either.

ACAP cannot justify to itself recommending the acceptance of the consultants' plan, calling as it does for static enrolment, small shifts of emphasis in fields, and no new developments in any department. We feel that the question of the best way to develop doctoral work in transportation and water resources must be more carefully canvassed and that whatever the answer be it must be adequately justified. Some evaluation of the quality of the programme in each broad field at each university must be available before we can make any credible recommendation.

ACAP would like, at this point, to draw attention to the Discipline Group's response, Appendix B. The members of the group feel the consultants did not "seize their unique opportunity to make quality judgements" and failed to "address themselves to the question of quality in the planning function in their conclusions and recommendations." The group thinks that a statement that "documents the sundry strengths and weaknesses, if they exist, could well increase the value to those on whom the responsibility for planning ultimately rests". ACAP therefore makes the following recommendation.

Recommendation C19

> It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

We regret that this recommendation is necessary. We note (page A-5) that the Discipline Group had not prepared for the consultants the report called for by the agreed procedure (page D-6). We note also that the consultants state that they "have formed (their) own judgement about the strengths of different civil engineering departments and the areas in which they are likely to be able to attract high quality students" - we regret that the consultants are not willing to share these judgements with the Ontario university community which employed them.

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

21 February 1974

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

Further to our recent telephone conversations, I have now heard from all my colleagues who fully agree with my letter to you of 4 December 1973.

As mentioned in this letter, we did not discuss the question of quality in our Report since none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

Moreover, we did not feel the need, nor were we required by our terms of reference, to make relative quality judgements regarding the strengths or weaknesses of individual areas or departments, because in our Report we did not recommend any change in the number or the range of doctoral programs offered by any school, including the various areas of specialization of the smaller universities.

Since the civil engineering discipline group, as well as most universities, find our Report on the whole acceptable, we think that little is gained by getting into an area which might be interpreted as an appraisal or accreditation assessment.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb
c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

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NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

4 December 1973

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

After returning from the west coast, I found your letter of 29 November and enclosures, which I read with interest.

In reply and following our terms of reference, we had not discussed the question of quality in our report since, in our opinion, none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

I am looking forward to the comments of my colleagues, in this regard.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb

c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

ADVISORY COMMITTEE ON ACADEMIC PLANNING
Ontario Council on Graduate Studies

Professor M. A. Preston
Executive Vice-Chairman

COUNCIL OF ONTARIO UNIVERSITIES
102 Bloor Street West, Toronto 181, Ontario
(416) 920-6865

Postal Code: M5S 1M8

November 29, 1973

Mr. B. V. Martin
Prof. G. G. Meyerhof
Prof. W. W. Eckenfelder, Jr.
Dr. J. L. Boulet

Gentlemen:

I am enclosing all the university comments we have received on your planning assessment report and the formal response from the Discipline Group. You will recall that it is intended to publish these statements.

You will see from the comments that there is considerable dissatisfaction in the universities and in the discipline group with your failure to come to terms with your task of giving us your findings on the relative quality of the doctoral work in the different areas of civil engineering in the different departments. We on ACAP have to agree that one of the most important aspects of the terms of reference you undertook is the statement of strengths and weaknesses of departments, and that without it the report lacks credibility. If you are asserting that all fields offered for doctoral work are competently dealt with wherever they are offered, it will follow that civil engineering is a paragon amongst disciplines. Even if true, it does not help the universities to decide which areas to strengthen.

In one of the few specific comments, you do suggest that McMaster should emphasize earthquake engineering. Do you think its work in water resources is strong enough that it should seek to expand or maintain that, or, when you recommend greater emphasis on water resources, do you expect this to be achieved at Ottawa, Toronto, Waterloo and Windsor for example? McMaster (and the others) would like to know. You tell the University of Western Ontario to emphasize boundary layer wind tunnel work; but what about their geotechnique? Since Guelph now has 5 students in its hydrology programme, how can it be exploiting its unique facilities for agricultural engineering if its enrolment becomes 4 to 7? Is it expected to cut back on hydrology? To consider this, it would be necessary to know how valuable Guelph's hydrology work is and how substantial is the potential of its agricultural engineering programme.

I mention these points only as examples of the kind of question on which your adivce would be helpful. The general point is that your judgements of quality by department and by area are important. You recommend that transportation be strengthened; we ask, where? If all the departments say "here", how are decisions about resource allocation to be made without the quality judgements you were expected to give?

....2/

One of the aspects of academic quality has to do with the size of the student enrolment. You will see from the university responses that there is some difference of opinion. The official position of COU, recently adopted, is as follows:

"The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design."

Recommendation 4 on page 52 of your report is not inconsistent with the above statement, but you do not indicate what criteria determine the "satisfactory environment." In ACAP we have identified two areas which we believe should be examined in this connection. One is the opportunity for the students' development through informal intellectual discussion with a peer group with common engineering or scientific interests. This peer group need not consist only of students; it may also include post-doctoral fellows. It need not be confined to one department, but may include students in other departments if there is a real sharing of research interests. The second main area for consideration has, we feel, to do with graduate courses. Assuming that a course with, say, 5 or 6 students who interact is a much more satisfactory experience than one with 1 or 2 students, we see that the desirable enrolment size is a function of course structure. If there were a programme which did not require courses, this second criterion of size would not apply. But if it is felt that students should take a substantial number of courses (as appears to be the case in all the Ontario departments), then the consideration is valid and the situation needs examination.

It appears that some of our departments plan enrolments as small as 6 to 12. It may be that some of these departments, because of specialization, course structure, post-doctoral and master's population and interdepartmental collaboration, offer an academically sound experience for the student, while other departments with the same enrolment may not. Each case needs evaluation separately.

This brings us back again to the desirability of your giving a detailed analysis of each university. We request evaluation of quality by area of study of each department, including an analysis of the kind of intellectual milieu established for a student by the enrolment size.

I hope you realize that we have a problem of reconciling the reports of the consultants on the various engineering disciplines. One report of which there seems to be pretty general approval is that dealing with electrical engineering. Of course not all its details are accepted by everyone, but the style and coverage of the report has not been attacked. I enclose a copy, since it may make clearer what I have been trying to say in this letter.

After you have had a short interval to consider the letter, I shall telephone Professor Meyerhof to discuss the mechanism of your response. We need your assistance.

Yours sincerely,

M. A. Preston

MAP/cew
Enclosures.

VII. ELECTRICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the electrical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C20

> It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

Other Discipline Groups might also consider this recommendation.

Recommendation C21

> It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

The work in electrical engineering at Carleton is divided into two departments, Electronics and Materials Engineering which includes solid state device electronics, circuits and circuit theory, microwave electronics and electron beam systems and processes and the Systems Engineering programme which concentrates on information systems such as communications and signal processing, decision and control, digital systems design and software engineering. The coverage within these two areas is well integrated, coordinated and appropriate for PhD training. The enrolment increase proposed by Carleton is within the competence and capability of the present staff.

Recommendation C22

> It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

McMaster has outstanding strength in three areas of graduate research and has plans to strengthen a fourth. These are communications and data processing, modelling and design, materials and devices and, lastly, medical electronics. The electrical engineering programme at McMaster is of high quality, with a productive and dynamic faculty.

Recommendation C23

> It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

The department at Ottawa specializes in three areas, communication systems, control and systems, and computer engineering. With a faculty of 11, the consultants felt that they were spread over a rather large area of electrical engineering. A small department with a small number of staff and students can operate an effective doctoral programme only with competent professors, complementary fields of study and an adequate research environment. The consultants recommend discontinuing the programme. ACAP has considered both the consultants' report and the university's comments and has concluded that Ottawa has a contribution to make to graduate electrical engineering study in operating a specialized programme of limited scope and enrolment.

Recommendation C24

> It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

The areas of specialization at Queen's are communications, systems, electronics, and energy processing. The consultants state that the work in communications is good but is only fair in systems, and that the Department should not offer a programme in the latter two fields on a regular basis. However, we suggest that an occasional student be allowed to do a thesis in one of these fields. ACAP accepts the consultants' view about enrolment which was made on academic grounds, not for planning reasons.

Recommendation C25

> It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

Graduate work at the University of Toronto covers seven areas including communications, computers, control, power devices and systems, solid state electronics, wave sciences, and biomedical electronics. The coverage of these fields is more than adequate and Toronto's "star-studded" faculty are spread over the seven areas indicating significant breadth across the department. The consultants conclude that the Toronto department compares favourably with any of the major institutions in North America.

Recommendation C26

> It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

The University of Waterloo concentrates in five major areas including computers and communications; control, systems and networks; devices, circuits and materials; power engineering; and, antennas and electromagnetic engineering. There are two minor fields, bioengineering and electroacoustics, and these fields should be limited in size to the present level of activity. With Waterloo's highly competent faculty and well-equipped facilities, there is no question that the enrolment level planned by Waterloo can be accommodated.

VIII. MECHANICAL ENGINEERING

There are a number of general recommendations and comments made in the mechanical engineering consultants' report that are aimed at the system as a whole. Recommendations for the individual universities follow this more general section.

The mechanical engineering consultants do not anticipate any oversupply of mechanical engineers. They believe no "artificial edict" is necessary to control the number of PhDs. On the contrary, they suggest the problem will be one of availability of good students. The consultants think that Ontario might, in fact, have a shortage of mechanical engineers.

"Traditional classical" versus "applied" research projects and a shift in emphasis of study are the next problems attacked by the consultants. They feel that the doctoral education of today should shift more towards project and design activity. To this end, they advocate increased dialogue and cooperation with outside agencies such as industry and government. "If we look at the problems before us today in the fields of energy, transportation, or the environment, it is apparent that there are many gaps in the knowledge which should be attacked systematically to provide the basic design data which is essential to advances in engineering and advances generally in technology on the broad front". The consultants also recommend a change in emphasis in fields of study. Some areas of research that need to be developed are listed on page A-14.

The consultants do not condone departments that attempt to be good in all fields. They feel specialization is the key and that "considerable selectivity is required in the choice of a particular area of concentrated effort". This choice of areas of concentration should be left up to the universities. ACAP agrees with this outlook but notes that the initiatives of each department in Ontario are matters for collective consideration and advice. ACAP advises the departments to consider the consultants' suggestions noted in the addendum and asks that they report on progress made after a year of mature consideration. After this time, the Discipline Group, in its normal role, would continue to consider the development of new areas of graduate study and the possible entry into neglected fields in mechanical engineering in Ontario and would make recommendations to ACAP where change is desirable.

Another problem the mechanical engineering consultants addressed was the one of faculty age. Since the Ontario universities have been through an expansionary period in the sixties, a large proportion of the faculty is below 45 years old, consequently lacking something in maturity and industrial experience. The consultants feel that although the retirements in the next several years will be few, the universities should take these opportunities to introduce new blood by appointing faculty with industrial experience.

It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendations

Recommendation C27

> It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

The Mechanical Engineering consultants, in their addendum, give valuable suggestions for focussing research activities in each department. These suggestions appear to be based on both planning grounds and grounds of academic quality, but alternative research foci may not be ruled out. Consequently, ACAP recommends that the three doctoral programmes continue but that each university note the consultants' comments and report on progress in a year's time.

Recommendation C28

> It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

The consultants, in their remarks concerning the University of Ottawa, page A-17, recommend that the work in the Mechanical Engineering Department be incorporated in an interdisciplinary programme leading to an undesignated PhD degree. ACAP notes the university response, page C-14, which states that they wish to "reactivate" the doctoral programme, before discussion of this new proposal. We do not at this time make a recommendation on the future form of engineering PhD work at the University of Ottawa. There appear to be no planning reasons why there should not be a programme at Ottawa in mechanical engineering, but the consultants have serious reservations about the suitability of a number of the research projects of the department and about the limited industrial experience of its staff members.

Recommendation C29

> It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

We draw the attention of the University of Toronto to the consultants' suggestion that the Department of Mechanical Engineering concentrate research on problems of major, national concern. UTIAS should note the consultants' comments on the need for selectivity within the broad spectrum of the expertise of the staff, in such areas as plasma science, low density gas dynamics, subsonic aerodynamics, flight dynamics, shockwave phenomena and noise. The consultants also favour increased interaction with work in related fields on the main campus.

Recommendation C30

> It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

ACAP notes the consultants' suggestion that the department concentrate in Production and Automation. We also take note of Waterloo's response which lists strengths in other areas. We recommend that Waterloo consider the consultants' idea of developing foci of research interest and report on any action thought desirable.

The University of Western Ontario and the University of Windsor have not been discussed here, since there is no need for any recommendations in addition to those in the section on University Recommendations, page 20.

IX. METALLURGICAL AND MATERIALS ENGINEERING

This section of the ACAP report will deal with the recommendations found in the metallurgical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C31

> It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these reommendations.

The consultants find it surprising that there is so little effort in the ceramics and glasses fields of study. Even more striking to them is the absence of any work in polymers in the Departments of Metallurgy and Materials Engineering. In their first few recommendations, they consider it very important to rectify these neglected areas and ACAP feels this is a job for the Discipline Group. They also feel it is important to strengthen already existing areas of study and in particular create at least one internationally-known centre of materials science activity.

Recommendation C32

> It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:
>
> a. recruitment of students with physics and chemistry backgrounds
>
> b. strengthening of the extractive metallurgy faculty
>
> c. collaboration with Toronto

The materials science programme at McMaster is considered by the consultants to be the best programme of this kind in Ontario and probably in Canada. It is the only programme that covers adequately the basic science related to all classes of materials including polymers. The enrolment could be easily doubled without developing the need for any significant increase in resources allocated to the programme, but enrolment, here, is limited as in so many other areas of engineering, by the number of qualified students.

The extractive metallurgy programme, although not as strong as the materials science one, provides very suitable research for the doctoral thesis. The range of the programme is, however, inadequate but cooperation with other McMaster Departments and with the University of Toronto will greatly enhance the operation of this programme.

ACAP suggests that McMaster consider the points put forward by the consultants and that the university report to ACAP on any action taken with regard to these recommendations.

Recommendation C33

> It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975 if a favourable appraisal is not obtained.

The consultants consider the programme in physical metallurgy at Queen's a good, traditional type of programme taught by young and talented faculty. Although it would make a suitable base on which to build a programme in materials engineering, the consultants do not recommend that Queen's do so.

The programme in extractive metallurgy, on the other hand, is not so well off. It is seen by the consultants to be inadequate in its present form, with too small a range of courses, too limited an amount of research activity, and ineffective interactions with other departments and programmes. But the consultants feel it is necessary to strengthen and develop this field, to provide the needed PhD graduates and maintain Queen's part in a history of leadership in Canada in mineral engineering, geology and related fields.

The enlarged programme of extractive metallurgy is envisaged by the consultants to consist of support from the Departments of Metallurgical Engineering, Chemical Engineering, Mining Engineering and Geology. ACAP realizes that cooperation cannot be legislated, but it must have some formal structure in order to make the various professors aware of their part in a cooperative venture and secure the recognition of their departments for the effort devoted to the venture.

Recommendation C34

> It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975 on any progress made in this direction.

Toronto has an international reputation for its graduate work in extractive metallurgy. However, the range of courses is limited; this situation could be improved through cooperation with McMaster. The consultants feel this would provide a good base from which to develop a programme in mineral engineering and extractive metallurgy and they advise the university to do so.

In addition to those who work in extractive metallurgy there is another group of professors in the department who describe their work as physical metallurgy and materials research. These people working with added specialists in polymers and electrical and optical properties of materials would form a group capable of mounting a substantial programme in materials engineering.

Recommendation C35

> It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Waterloo has no specific programme in materials and does not offer a PhD labelled as metallurgical engineering or any allied field. Instead, students are trained in extractive metallurgy in the Department of Chemical Engineering and there is a group of metallurgists and materials scientists in the Mechanical Engineering department. The consultants felt their effort was of such high quality that if this group were constituted as an administrative unit, they would be the strongest and most comprehensive graduate programme in materials engineering in the province. The consultants recommend setting up a separate administrative structure. However, the unit (all in one department) appears to function well without separate administration and ACAP does not feel that such a structure is imperative. Waterloo will, no doubt, consider the consultants' suggestion.

X. MINING ENGINEERING

Queen's University offers the PhD in mining engineering. This is unique in the province. Although the enrolment is small, the programme appears to fill a distinct need. The University projects no enrolment increase, showing only 4 students in 1977-78.

On the basis of the statement of future plans made by the University, we recommend:

Recommendation C36

> It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

XI. INDUSTRIAL ENGINEERING AND SYSTEMS DESIGN

This section of the ACAP report will deal with the recommendations found in the industrial engineering and systems design consultants' report. It will contain recommendations on the Universities of Toronto and Waterloo. ACAP suggests that the University of Windsor take careful note of the recommendations made in this consultants' report but at this time ACAP makes no specific recommendations on doctoral work in industrial engineering at Windsor since it is part of the earlier Recommendation C11.

The general recommendations in this report echo many of those found in the earlier consultants' reports. These consultants' estimates of manpower supply and demand closely follow those made by the other consultants and are discussed more fully in the second part of this ACAP report. Related to this is the need to increase the Canadian content in engineering programmes. Recommendations C1 and C3 refer specifically to these two points.

ACAP notes that the universities do not consider the establishment of a co-ordinating committee to be very important. We hope that talks are normally taking place between the three departments and that they will continue. ACAP feels there is no need to set up a formal Discipline Group to ensure discussions but if those concerned wish to do so it can be arranged.

Again, as in the other consultants' reports there is seen to be a need to circulate information to the student concerning the various programmes in order to ensure he selects the programme best suited to his objectives. This problem has been addressed by Recommendation C7.

ACAP endorses the consultants' recommendations 6,7,8,9 and 11 and does not wish to make any particular comments on these recommendations.

Recommendation C37

> It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

In its response to the consultants' report, the University of Toronto seems in general agreement with the recommendations made concerning its programme. ACAP notes that the Department has already made the appointment suggested in recommendation 3.

As far as future enrolment is concerned, ACAP suggests the university continue to expect approximately the same enrolment as it now enjoys. In accordance with standard appraisal procedures, a shift in fields of specialization to programmes in health systems and energy systems would require referral to the Appraisals Committee to determine whether or not an appraisal is necessary.

A review of the enrolment expectations would be made at that time. For the present, a continued output of 3 or 4 PhDs a year should be expected by the university. This should not be regarded as a quota but rather as the outcome of the present situation of fewer qualified students and falling enrolments. It should be noted that the University of Toronto has maintained a high percentage of Canadians in its industrial engineering programme in comparison to other engineering programmes both in the University of Toronto and elsewhere.

Recommendation C38

> It is recommended that the University of Waterloo continue its doctoral programme in systems design.

ACAP takes note of the response of the University of Waterloo to the consultants' various recommendations concerning the Department's isolation, its "soft" course content and the quality of recent staff appointees. Despite the possibility that enrolments may increase in this field and despite the comments from the University, ACAP considers that Waterloo should give careful attention to the consultants' recommendations for strengthening the programme before increasing the enrolment.

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APPENDIX A

REPORT

OF

MECHANICAL ENGINEERING CONSULTANTS

TO

ADVISTORY COMMITTEE ON ACADEMIC PLANNING
ONTARIO COUNCIL ON GRADUATE STUDIES

H.W. Emmons, G. Ford, R.D. Hiscocks and S.G. Mason

October, 1973

TABLE OF CONTENTS

Page

I. INTRODUCTION A-1

II. CONTENT OF THE REPORT A-2

III. MECHANICS OF THE ASSESSMENT A-4

IV. NUMBER AND QUALITY OF STUDENTS A-5

- A. The Supply of Students A-5
- B. Foreign Students A-6
- C. Employment Opportunities for Graduates A-7
- D. Student Concern about Career Opportunities A-8
- E. Quotas on the Number of Students A-9

V. ANALYSIS OF MECHANICAL ENGINEERING EDUCATION AT THE DOCTORAL LEVEL A-10

- A. Course Requirements A-10
- B. Doctoral Theses A-10
- C. Thesis Work Outside the University A-11
- D. Part-time Studies A-12
- E. Coverage of Mechanical Engineering at the Graduate Level A-12
  - Table 1 - Some Underexplored Mechanical Engineering Problems A-14
- F. Graduate Programs - Strengths and Weaknesses A-15
- G. Industrial Research Institutes A-16

VI. GENERAL OBSERVATIONS A-16

- A. The Minimum Size of a Group A-16
- B. Department of Mechanical Engineering - University of Ottawa A-17
- C. University of Toronto - Institute of Aerospace Studies A-18
- D. Metallurgy/Material Science A-19
- E. Faculty Age Distribution A-20
  - Figure 1 A-21
- F. Staff Mobility A-22
- G. Financial Support for Graduate Work A-22

VII. RECOMMENDATIONS A-24

APPENDIX A: Opening Statement Made at Each Site Visit A-26

ADDENDUM A-29

I. INTRODUCTION

Mankind has recognized the engineer and his work over many centuries. The name and connotation arise from the latin "engenerare" - to create. In the modern sense, however, engineering dates from the time of Galileo who with his "two new sciences" introduced for the first time the laws of cause and effect together with an ability to predict and design. He added science to the art and made that the basis of engineering. One might therefore define engineering as the creative application of the physical sciences to the solution of problems for the benefit of mankind. The characteristic problems attempted by engineers have, over a period of time, categorized the various branches.

In early times there were two broad classifications, the military and civilian. As the civilian aspects of engineering grew and the demands for energy and more efficient machines increased, there developed a specialized segment who became known as mechanical engineers. In the late 1800's another group of specialists in the electrical area began to emerge, until today we have many sets and subsets within the wide context of engineering.

Mechanical engineering by its nature is a highly-diversified discipline ranging from applied mathematics and physics on the one hand to an empiricism verging on black magic on the other. In content, there is a wide range of topics generally embracing three main areas - solid mechanics, fluid mechanics and thermo sciences. Although all good departments will have some expertise in each of these areas to provide the breadth necessary for a sound understanding of a broad range of topics, they will generally have depth in one or at the most two of the main subsets. Within these main subsets there can be a wide variation in emphasis. Hence there can and will be several departments whose main strength will be, for example, in fluid mechanics without there being any significant overlap in effort.

Additionally, the problems confronting our technological society require an increasing understanding of the social and economic sciences. Therefore, in most departments, at all levels of instruction, there should be an intimate interface with the social sciences. Increasingly, the engineer must become aware of the ever extending economic and social consequences of his work. For this he must have some competence in economics and a sensitivity to social, psychological and political forces, thus emphasizing the need for breadth in the mature professional. The mechanical engineering faculty, therefore, have a particular responsibility to understand the true significance of this role.

Although the graduate program at the PhD level in the Ontario system can, for the most part, be considered as just emerging, we were pleased to see a broad spectrum already developing. In several areas, however, we recognized there was too great an effort in the more traditional and classical areas of research. We suggest that this effort be redirected, with more emphasis placed on the practical background of the theoretical solutions and strengthening the basic understanding of the empirically developing areas.

II. CONTENT OF THE REPORT

The academic discipline of mechanical engineering is broad and not amenable to categorical definitions. In order to assist us the Ontario Discipline in Mechanical Engineering provided a list of factors which were to be considered in developing an assessment of the educational program of doctoral students in engineering. At the outset, we wish to express our general agreement with the guidelines. In our opinion, centralized coordination and planning of doctoral programs on a provincial-wide scale must be avoided as far as possible in order to develop the full academic potential of each department. We agree that a doctoral program in every department is essential. Not only does it ensure a dynamic modern undergraduate curriculum but it also contributes to a competitive in-house research atmosphere which enhances the excellence of any program, and provides both students and faculty with opportunities to develop native ingenuity and innovative skills so necessary to our technological society. It is from a well-developed broad background with an in-depth maturity in a specific segment that a well-balanced and mature professional engineer emerges. We further believe that group size has little effect and with some variation successful programs can exist in small, as well as large, departments.

One of the ways in which the university serves society is to screen and sort young people. The sorting process determines who is capable of entering, continuing to graduation, undertaking graduate work, and who is qualified to receive an advanced degree. Many people object to yielding such tremendous power to the faculty and the university community. However, no better way has yet been found. We are in accord that the existing methods of selection be continued. We do not believe in centralizing this screening process.

Having picked a career in which the demand for special skills can change rapidly from time to time, the engineering graduate at all levels must be sufficiently flexible in his competence to qualify for employment in a wide variety of activities. Only in this way is there hope of bringing supply and demand close to balance in the face of inevitable fluctuations in the economy. A broad base with an in-depth study in a specific area is therefore a major requirement in the design of a PhD program.

On the other hand, our terms of reference caused us some concern because their generality made it impossible to fit exactly all conditions. Nor can specific answers or recommendations be made in all cases. The very nature of the programs considered will dictate, to some extent, the reply to posed questions. Nevertheless, we viewed them as useful guidelines for our inquiries, but we have responded in ways emerging from our analysis of the situation. To reply otherwise would negate the exercise. In the end, the choice of alternatives became a matter of judgment; no set of rigid criteria could be expected to yield a clear-cut decision. There is always a measure of subjective weighting placed on each of the factors used to arrive at a conclusion. It is hoped the collective weighting will lead to a sound judgment.

There are strong indications that a new era is emerging in Canadian industry which recognizes the need for the backing of a highly-developed technology if it is to satisfy its nationalistic aspirations while competing in the world markets. The evidence of an increase in demand for engineers, at all levels of academic attainment, is increasingly noticed.[1] Not only is there an alarming indication of an impending severe shortage of engineers in total but there is every indication of a gross undersupply of mechanical engineers and a strong suggestion that there will not be a sufficient number of academically able students to meet the minimal demands from industry for well-qualified PhD graduates.

The Ring of Iron[2] was completed at a time when society viewed engineering and its physical sciences with suspicion. In contradiction to a major premise of that report the consultants found no evidence that Canadian industry was passing from a primary to a tertiary position without passing through the secondary stage. Instead our findings tend to indicate a rapid strengthening of the industrial base with a corresponding increase in demand for high-technology support. In the two-and-a-half years since the release of that report, there has been a dramatic change. Our review was conducted as Canada approaches the threshold of an impending shortage and heavy demand for mechanical and other engineers. So rapid is the change that in the six intervening months between the writing of the terms of reference and the commissioning of this report, many of the specific questions posed are no longer meaningful. The emerging immigration policies and market forces alone will be sufficient to determine the size and distribution of the PhD student body. Quotas as such will be without meaning, since they can never be met. The recognition of the emerging upsurge in engineering has had a very significant impact on our assessment of the PhD programs in mechanical engineering in Ontario.

In this light then, we will now try to sort out and assess in greater detail conditions as we found them.

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[1] This statement (for mechanical engineering) is at variance with report Supply and Demand For Engineering Doctorates in Canada, Canadian Engineering Manpower Council, July, 1973, which predicts an oversupply of PhDs in engineering in the decade ahead.

[2] Ring of Iron, A Study of Engineering Education in Ontario, December, 1970

III. MECHANICS OF THE ASSESSMENT

Each of the Mechanical Engineering Departments in the eight universities offering graduate work was visited.[3] The Institute of Aerospace Studies at the University of Toronto was also included in our itinerary and was reviewed in the same general way as the others. Special mention of it and of the Department of Mechanical Engineering at the University of Ottawa is made later.

In all nine departments there are 156 faculty involved in teaching mechanical engineering at all levels. Of these, over 100 were interviewed individually, in small groups or in plenary session; 25 or more administrators (Presidents, Vice-Presidents, Deans of Engineering and of Graduate Studies and their assistants) were consulted; and finally the views of representative groups of PhD candidates or recent graduates, numbering over 50 in all, were obtained. Nowhere did we uncover any evidence of an oversupply of PhD graduates; statistics were produced[4] to show that all past graduates were usefully employed, many in places of high responsibility with many of the recent graduates having received multiple offers. In only one case did we find a PhD graduate holding a post-doctoral fellowship because he could not find permanent employment.

The assessment of each Department was carried out as consistently as possible. The time spent at each varied between 1 and 1½ days. The same general agenda was used at each place as follows:

1. Meet department chairmen to review agenda and other general points (¼ hour).
2. Plenary meeting with all staff at which the consultants made an opening statement[5] and an open forum was conducted. This laid the foundation for a closing plenary session at which time the views of the staff were consolidated (1 hour).
3. Meet administrators (the timing varied depending on the schedule of the administrators) (½ to 1 hour).
4. Visit laboratories and graduate research projects (1 to 2 hours).
5. Lunch with continued discussion with staff or administrators (1½ hours).

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[3] Carleton, McMaster, Ottawa, Queen's, Toronto, Waterloo, Western and Windsor.

[4] List of PhD graduates and their present employers were provided at Queen's, U.T.I.A.S., Waterloo, McMaster and Western. Verbal reports were received at the others.

[5] See Appendix A, attached, page A-26.

6. Interview graduate students and recent PhD graduates (1 hour).
7. Interview individuals, research or specialized groups (1 to 2 hours).
8. Reconvene in plenary session and final views obtained (1 to 2 hours).

Squeezed in: (i) review of admission files of selected students
(ii) reviewed or scanned several PhD theses[6]

IV. NUMBER AND QUALITY OF STUDENTS

A. The Supply of Students

At the present time there are 150 mechanical engineering PhD candidates in the Ontario system. This counts only those graduate students who are beyond the master's degree or who have been accepted for the PhD without a master's. Why 150? What controls this number? If you ask, as we did, the average faculty member how many graduate students he would like to have, you get the answer "about 2 PhDs and 3 or 4 master's candidates." At present there are 156 mechanical engineering faculty in Ontario and thus there is almost exactly one PhD candidate per faculty member. The size of the faculty does not control the number; they could handle twice as many.

The facilities for research that we have seen on our visits have been excellent. Except in a few special cases, there is no limitation on PhD study set by either apparatus or laboratory space.

The question of financial support is harder to dismiss. There were complaints about excessive stipends paid to PhD candidates by "other" institutions both in Ontario and in the U.S. Such complaints could not be backed up by hard data and were contradicted by the occasional student who came to Ontario attracted by the "higher salary offer." Both from the meagre data collected and from our own knowledge of the financing of PhDs here and in the U.S., we believe the Ontario system to be "in line" and competitive. This is not to say that you could not attract many more PhD candidates by doubling the salary offers. Of course, you could. But such a course of action is unjustifiable both for Canada's need for mechanical engineering doctorates and Canada's needs in other areas which would then be robbed.

The real limitation to the mechanical engineering doctoral candidate population is the availability of "good" candidates. The temptation under such circumstances is to lower the admission standards.

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[6] A selection of staff research publications, most of which were based on graduate student research was examined separately.

It is to the great credit of all of the Ontario system that this temptation appears to us to have been avoided. In every case the PhD admission standards were set at a reasonable level and jealously guarded by extensive departmental and graduate school rules and procedures.

The evaluation of human qualifications is a very difficult and highly-subjective process at best; there is no reason to suppose that all faculty members or all institutions would arrive at the same conclusion when examining borderline candidates. Thus, it is of little wonder and no significance that every institution can quote cases where someone they rejected was accepted elsewhere.

Thus, we reject the notion that any unjustified significant systematic differences exist between institutions on the level of PhD candidate acceptance.

The main obstacles are the ability and motivations of the present generation of students. Science in general and technology in particular, after the heyday of the space program, are popularly seen as the causes of our pollution, energy crisis, and other problems. Although this view is wrong and will change, the change will be slow. Thus, we do not see any reason to anticipate an oversupply of mechanical engineering PhDs in the near future. On the contrary, we see a shortage. Since more good candidates cannot be produced on order and then only by robbing other areas, we believe that the control of PhD candidates should continue to be by their availability and not by artificial edict. The competition to provide the best and most useful educational program is a better key to the future than any planned PhD production schedule, however based.

B. Foreign Students

Presently at the PhD level only 40 students in a total of 150 have taken their first degree at Canadian universities. Although a small number of Canadian baccalaureates go abroad for the PhD degree and return, it is clear that we cannot count on Canadian undergraduate schools to provide candidates in sufficient numbers: to avoid a drastic reduction in enrolment and output they must continue to come from abroad. Of the present 150, 74 are landed immigrants and 19 are on student visas, most of the latter from underdeveloped countries. The contemplated changes in immigration policies (which will make it more difficult to attain landed immigrant status) and the funding policies of N.R.C. and other granting agencies (which prohibit support of those on student visas), will seriously reduce the number of foreign students in the future.

We recognize that Canada as a wealthy nation has a commitment to support students coming from (on student visas) and returning to developing nations and to assist these nations with their emerging universities and industries. This commitment should be national rather than provincial. We would envisage all graduate students entering Canada from countries that do not have a well-developed industrial economy would do so on student visas under the auspices or purview of an appropriate federal agency such as C.I.D.A.[7] It is not unreasonable to expect as part of Canada's foreign aid that the educational expenses of these students be borne by C.I.D.A. Each Canadian university accepting a student under the purview of C.I.D.A. would be compensated at the level of the student support within that province. In this way, part of Canada's contribution to the developing nations could be met through a meaningful educational program without imposing an undue hardship on provincial educational budgets.

C. Employment Opportunities for Graduates

We discussed the employment opportunities for recent graduates with all staff members and all were emphatic in stating that the difficulties reported a year or two ago, which may or may not have been real, do not apply to PhD graduates in mechanical engineering today. They cited examples of recent graduates receiving numerous job offers, mostly from industry and aimed particularly at graduates who have specialized in production engineering. Of the approximately 50 students interviewed with a PhD in mechanical engineering (recently granted or pending) only one reported difficulties in finding permanent employment. One graduate, who majored in production engineering, listed for our benefit six firm offers of employment.

While employment opportunities undoubtedly will continue to fluctuate we do not believe that the demand we see today should be regarded as unusual, or temporary. When we examined the employment record of some 150 graduates with a PhD in mechanical engineering (including aerospace) we found a wide distribution of employment in industry, the universities and government. The positions reported do not reveal any "underemployment" of the PhD and the records which extend back over a period of years show that the older graduates occupy senior positions of high responsibility.

It is recognized that the staff requirements of the universities will be small (see Part VI. D.) in the future and the main source of employment in Canada will be outside the university and mainly in industry. Most of the 600 "high technology" firms that engage in research in Canada are in Ontario, and with the increasing demands for new and innovative industries which can compete in the world market we would expect increases in their number and diversity. The experience with the N.R.C. Industrial Post-Doctorate Fellowship program leads us to believe that many of the 60,000 firms in Canada, approximately 40,000 of which are in the manufacturing industry, can employ the PhD to good advantage, not necessarily in research. The new and developing procurement policies of the federal government, the emphasis on cleaning up the environment, on new energy sources, better rural and urban transportation, etc., will certainly create an increase in the demand. Against this increase in demand we must weigh the fact that the output of graduates will diminish substantially, possibly as much as 40%, as the result of the anticipated decline in enrolment of new candidates with acceptable qualifications. The picture of a possible shortage becomes even more probable when we recall that in the U.S.A., government agencies and professional organizations are expressing serious concern that a substantial shortage of engineers will develop in that country in a few years. If this happens, the experience of the 50's, with a large "brain drain" of qualified engineers out of Canada, may be repeated. In view of all of these considerations we find it difficult to believe that an annual output of 20 to 30 PhDs in mechanical engineering from the Ontario universities will be in excess of the demand. On the contrary, it is easy to predict a serious shortage.

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[7] Canadian International Development Agency

Although better information on job opportunities would be welcomed, and a central "clearing house" of information might be useful, the point was made in many discussions that one should be very cautious in the interpretation of "demand" surveys - particularly in industry. The businessman can rarely predict his firm's requirements in advance, and on those occasions when he can he is not likely to reveal it. "One of the least reliable ways for finding out what industry wants is to go and ask industry."[8] We commend those engineering departments which maintain an up-to-date historical record of the careers of their graduates; we urge all departments to adopt the practice, and to see to it that the information is made widely available to counter the negative views which appear frequently in the press.

D. Student Concern about Career Opportunities

We were surprised to find that most of the students we interviewed expressed concern about the job prospects after graduation. Few seemed aware of the recent upturn of job opportunities in industry, and very few seemed to have any idea of how to approach a firm or how to establish contacts outside the university. In some of the universities visited we were told that "placement officers" assist the students in these matters. If this is so it would appear that the graduate students either do not use these services, or they leave the investigation of job opportunities until very late in the day. We did not go into this in any depth, but it was clear that the majority of the students who were interviewed had little appreciation of the structure of Canadian industry and little knowledge of the firms that engage in the development of new technology nor of their prospective staff requirements. To explain this we must assume that the students have been badly served by the "popular" news media, the technical press, the placement agencies, and the universities themselves.

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[8] Statement attributed to Sir Solly Zuckerman. See page 112, Canadian Engineering Manpower Council Report, Supply and Demand for Engineering Doctorates in Canada, July, 1973.

E. Quotas on the Number of Students

From the foregoing observations we believe it is clear that an annual output from all of the Ontario universities of 20 to 30 doctorates in mechanical engineering will not be excessive and will not saturate the job market. We believe the developing market could easily absorb double this rate of output during the next five years. In saying this we are not advocating a return to the "open" system of a few years ago when the growth of graduate schools and budgets was virtually uncontrolled. There is an obvious need for a better understanding of the factors that govern the supply and demand of qualified engineers with advanced degrees. To date even the best available data are viewed with suspicion. Definitive studies with much narrower confidence bands are urgently needed. In the absence of reliable data and in view of the emerging natural controls we concluded it was neither rational nor wise to propose a total enrolment figure with a corresponding distribution throughout the system; rather we would wish the resources of the present system which are predicated principally on undergraduate requirements, the market demands, the quality of program and the good judgment of the departments to determine the total number within the system. In this regard we consider the system, in its present form, can accept up to 300 PhD candidates or an average of about 2 per staff. However, our best estimates would suggest there is little likelihood of achieving such an enrolment during the next five years; and although we have little or no quarrel with the projected figures found in the five-year plans we have grave doubts that even that total of 170-180 will be attainable by 1978.

In the same way we find it difficult to apportion the distribution of candidates between the various universities which offer graduate programs. At present a student has a wide range of choices and in our interviews with the students and discussions with staff members it was apparent that Canadian students contemplating graduate work are generally well aware of the courses available in the various institutions, of the outstanding teachers, and of the strengths and weaknesses of the departments. The capacity of the individual departments, as we have noted previously, is ample.

V. ANALYSIS OF MECHANICAL ENGINEERING EDUCATION AT THE DOCTORAL LEVEL

A. Course Requirements

We have assumed that the PhD degree in mechanical engineering signifies that the holder has an advanced education which permits him to not only perform the usual design and production tasks in his field but also to attack successfully many complex problems and to perform research in engineering science. To do these things requires a broad knowledge of his field, some understanding of related areas, and experience in how to proceed.

These educational objectives are attained by requiring the candidate to take a number of graduate courses, to pass a qualifying or comprehensive examination and to prepare a doctoral thesis. It appears to us that the desired breadth of knowledge is best attained by a total of about 1½ years of full-time course work beyond the Baccalaureate degree. Most universities now require this. A few do not, but we believe they should. Of course, a student can get his breadth by self-study but very few would do so. A smaller course requirement would more often be used as the easy way out.

The thesis is universally used as the study in depth. In the thesis area the student is motivated to self-study so that only a few of the courses taken should concentrate heavily in the thesis field. Thus the offering of a large number of highly-specialized courses (with very few students in each) which we noted in several departments is not justified educationally and is certainly not an economic use of faculty time.

B. Doctoral Theses

In the course of our visits to each university, we made cursory examinations of a few doctoral theses. However, this examination, when combined with discussions with faculty and students, and often with prior knowledge of the subject by the consultants, additional useful information was obtained. Most theses were indeed reports on creditable doctoral work. Each student displayed a broad view of his special field, he analytically (and numerically) studied the predictable performance of the device or process, he obtained in the laboratory (or occasionally from pertinent literature) the actual performance, he carefully compared the theoretical and experimental results, and finally analyzed and discussed the discrepancies.

However, we occasionally met the inadequate thesis which leads to an inadequate graduate. These were of two kinds: the completely theoretical thesis which solves by a well-developed mathematical routine another minor variant of a problem which abounds in the literature and with little or no engineering justification; and at the other extreme, we occasionally spotted a thesis in which a purely empirical attack was used to solve a problem which might or might not have practical application.

In both cases we believe the education of the candidate was incomplete. In the first case, he had no training in ingenuity - and thus learned little that is in demand by industry (and should not be in demand for university teaching either). In the second, he had no training in the formulation in quantitative form, of the qualitative ideas which he believes makes his empiricism work. His work could have - and probably should have - been done in industry. The real opportunity of the university to educate was lost.

C. Thesis Work Outside the University

While "project work" of the kind suitable for a M.Eng. thesis is readily found in many industrial and government agencies, it is more difficult in this environment to organize a program of research with the content, analytical and experimental, needed to satisfy the requirements of a PhD thesis. When these difficulties can be overcome there are obvious advantages in bringing the students close to the problems of industry and in providing access to people with unique training and highly-specialized facilities. It is highly desirable that the thesis be of interest to the host organization and that, wherever feasible, it be supervised jointly by a staff member of the university and of the host organization.

A problem which is raised frequently in discussing such cooperative ventures is that of the "proprietary" rights of industry. In our discussions it was generally agreed that this problem is often more apparent than real. There must be a clear understanding in advance about the sharing of patent rights and delays in the publication of research results. "Secret" projects generally are not acceptable for PhD theses.

While practices vary widely between universities, several departments reported success in their cooperative ventures with high technology firms such as Bell-Northern, AECL, and Westinghouse, and held out hopes for further progress as the result of a growing interest in industrial research, the new contracting-out policies of government agencies, and the PRAI[9] grants of the N.R.C.

We urge that all of the university departments offering advanced courses in mechanical engineering encourage frequent contacts and firm cooperation with outside agencies. The importance of this liaison, at a time when there is general agreement on the need for postgraduate training to be more closely matched to the needs of employment, cannot be overemphasized. One student commented that in his thesis research he had enjoyed the best of both worlds - industry had provided the required relevance and the university had provided the essential underlying science.

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[9] Project Research Applicable in Industry

D. Part-time Studies

We examined the experience of the various departments with PhD candidates who undertake part-time studies in conjunction with a full-time job. There is no doubt that part-time courses and projects at the Master's level have operated with reasonable success. Beyond the Master's level progress becomes much more difficult and many doubts were expressed about the abilities of the most capable candidates to meet the minimum requirements of a PhD program.

From the experiences reported we have concluded that the burdens upon the student, his family, the employer and the university, are out of all proportion to the chances of success in most instances. While we recognize that it would be unwise to deny the exceptional student an opportunity in a special situation we recommend that such undertakings should rarely be encouraged.

E. Coverage of Mechanical Engineering at the Graduate Level

Mechanical engineering encompasses all manner of mechanical devices and processes used by man. At its base lie the sciences of mechanics (including kinematics and vibrations), solid mechanics (including elasticity and plasticity), fluid mechanics (including acoustics), and transport phenomena (including conduction, convection, diffusion, and radiation). And the basis for all of these are the laws of classical physics - mostly mechanics and thermodynamics - made useful through the methods of modern applied mathematics.

Every mechanical engineering department in Ontario has a faculty capable of offering the core graduate courses in each of the above areas which should be part of the breadth of every PhD. In every department, the faculty is capable of supervising theses in the classical basic problems of mechanical engineering - dynamics and vibrations, elastic structures, fluid dynamics of simple fluids, and heat and mass transfer.

But is this adequate for the 1970's? We think it is not. Only in the rare instance (as can easily be judged by examining the resultant published papers) does the thesis advisor or his PhD student have so potent an idea that a real advance is made in classical engineering science. Most often the result is a thesis or a paper with little permanent value and no engineering significance.

Yet mechanical engineering abounds in important and challenging problems. Some members of the faculty at each Ontario university have realized this and have moved with their research into some more important and contemporary area. Thus we found work on such diverse and useful problems as extrusion of metals, machine tool automation, thermal contact resistance, the drying of paper, and the motion of aerosol particles. Manufacturing industry is concerned with all of these questions and many more. The Canadian industry already carries out some research, albeit largely empirical, in these areas and we would all like to see it carry out more. A thesis to develop an understanding of and to provide basic data in such areas provides the student with an innovative challenge and the preparation for future work which Canadian industry needs.

To exercise ingenuity in redirecting one's own efforts from an old familiar classical path to an innovative new effort is difficult. It is common for ideas to become "popular" and for many people to move in the same direction at the same time. Thus there are already several closely-related efforts in metal cutting and machine tool performance and control in the Ontario universities. These efforts do not yet involve serious overlap but they could easily do so in the future.

Such close parallel developments could be justified, if the possible areas of mechanical engineering need were few in number. However, this is not so. In the following table we give a partial list of some important mechanical engineering problems in which little or no research effort is to be found in the Ontario educational system and in which there are significant and challenging problems of basic science and useful data development suitable for PhD theses. This list is so extensive that many items would go untouched even if the entire mechanical engineering faculties devoted themselves to these problems.

Thus, we believe that most of the research effort now expended on classical mechanical engineering science could profitably be redirected toward innovative studies of more urgent problems which arise in mechanical engineering practice. We have no serious reservations about the extent of coverage in the present programs, certainly not to the point of suggesting the termination of any. On the other hand, we would urge the expansion or creation of new programs be directed toward the areas listed. We caution, however, against the temptation to attack these problems in a purely empirical way. To us the good PhD study in "mission-oriented research" is a fundamental study of the basic processes and principles in the appropriate range of the significant dimensionless parameters with an application of the results to real industrial engineering problems.

We believe this change in emphasis would strengthen the faculties and would attract industrial research support. Furthermore, it would cause industry to clamour for the new PhD graduate and would make more good students aware of the importance of advanced studies.

BEST C

Table 1

SOME UNDEREXPLORED MECHANICAL ENGINEERING PROBLEMS

POWER TRANSMISSION

hydraulic transmission, belt friction, wear and noise, gear noise.

TRANSPORTATION

the urban problem car, system analysis, emissions, rail improvements. Noise generation by transport systems.

ENERGY CONVERSION

steam and gas turbine flow, thermal and dynamics problems, space power cycles, thermoelectrics, thermionics, fuel cells, solar energy devices, heat pumps, cryogenics.

FLUID SYSTEMS

piping system design in the linear and nonlinear regions, hydraulic power transmission, ventilating system design and control under normal and emergency (fire) circumstances.

TRIBOLOGY

lubrication, friction and wear.

MULTIPHASE FLOW

industrial processes with the full range of significant parameters, aerosol dispersion, flow of dust and sediments, blood flow, wet and dry paper fiber transport and laying, the boxing of cereals, the flow of dry cement and nails, the pumping of concrete and roofing tar, the slippage of earthen dams, etc.

SOLID SYSTEMS

aircraft and space system structures - optimization. Creep, fatigue, and fracture of engineering structures. The design and performance of composite materials and structures. Pressure vessel design the critical problems of access openings. Nondestructive testing.

PRODUCTION PROBLEMS

plastics molding, fiber handling, drying processes, casting processes, materials handling equipment, furnace design, incinerator design, combustion control, ignition, growth and extinguishing of fires. Environmental systems design and control.

Most manufacturing industry would profit from a first-rate mechanical engineer with a PhD. Most industries have not yet learned this. Will they? When?

F. Graduate Programs - Strengths and Weaknesses

As we have noted above, it has been the tradition of universities in this country to encourage analysis and research. The efforts to generate interest in the other essential aspects of engineering - and to provide the appropriate training - have been comparatively recent. In our round of visits it was apparent to us that interest in these neglected subjects has been growing to the point where project engineering studies, for example, are widely accepted as vehicles for M.Eng. theses.

It was our impression that progress in the teaching of design has been much less rapid, and the extent to which it has been accepted and integrated into the graduate programs is highly dependent upon the energy and enthusiasm of a small number of dedicated professors rather than a general conviction of the faculty as a whole.

Production engineering, it appears, is beginning to make an imprint on graduate studies and we were encouraged to find two groups which were making a determined effort in this field, and at least one other working on a more restricted basis. All of this work was of high quality, and we considered it a very healthy sign that all the production-oriented groups with which we met had close contacts with industry which created an excellent market and a high demand for their graduates.

When we compare the Ontario level of effort in design and production with its counterpart in Europe, it is all too clear why our manufacturing industries are sceptical of the value of a PhD, and why the firms often recruit highly-trained engineers from outside Canada. We therefore consider a design effort should be encouraged and if possible incorporated into every PhD program and production engineering at the graduate level strengthened and expanded in those departments which have developed a competence in this area. The work at McMaster and Waterloo is noteworthy in this regard.

Each department exhibited strength in more than one area. Any shortcomings were not considered serious and were not confined to a particular department. With the exception of Ottawa, we would not recommend any re-appraisals, nor would we wish to specify any direction of effort. We found the five-year plans generally acceptable, with no serious gaps or areas of overlap. However they were, in our view, somewhat lacking in imagination. We reiterate our belief that the departments seriously consider some redirection of their efforts to the solution of some of the more urgent problems which underlie mechanical engineering practice.

G. Industrial Research Institutes

A number of Ontario universities have obtained assistance from the federal government and other sources to establish on-campus industrial research institutes. The object of these institutes is "to provide scientific services to firms with limited resources, to make available to industry the trained manpower and specialized facilities available in the universities, and to provide the universities through a close association with industry with an opportunity to coordinate more closely their educational and research programs with current industrial requirements."

We did not meet all of the institute directors, or discuss the operations of the institutes in detail, but in the light of our observations and conversations we wish to record our conviction that these institutes are highly beneficial to the research of the faculty and to the relevance of their work.

It is recognized by the institute staff and the faculty that some safeguards are necessary, but we saw no evidence that in serving the short-term interests of industry there was any tendency to lose sight of the long-term objectives of the university.

VI. GENERAL OBSERVATIONS

A. The Minimum Size of a Group

We were often asked for our views on the minimum size of a viable group at the graduate level. The advantages enjoyed by a large group, with a wide variety of talents and extensive resources are recognized and require no elaboration. A drawback to a large group is the difficulty of adapting to change. The majority continue to be organized along vertical lines according to discipline and although the desirability of functional groupings, along horizontal lines, is recognized and has been achieved to some degree, the discipline-oriented structure continues to dominate. On the other hand we observed that the groups in the smaller departments often displayed an original point of view and a willingness to adapt to change that was not apparent in the larger and longer established departments. The cross linkage between departments within small faculties was noticeably more distinct, tending to create an educational milieu that fostered high order graduate work. Ottawa, Queen's, Western, and Windsor all had working relationships with their counterparts in civil engineering. We also noted that there was a tendency on the part of the small departments to compensate for shortages of internal resources, intellectual or physical, by establishing outside contacts. The relationships that have developed between Carleton, Ottawa, Western and the government agencies such as the Atomic Energy of Canada, the Forest Products

Laboratory, and the National Research Council, indicated a healthy outward-looking viewpoint while at Windsor their relationship with the Industrial Research Institute brought them into contact with the high technology problems of industry. Interdepartmental cooperation on a wider university scale was evident in areas of environmental control and bioengineering. In these emerging fields the smaller departments were as actively occupied in high-level research as were their counterparts at the larger institutions. We think the vitality of engineering to an increasing extent will depend upon the ability to anticipate change as well as to adapt to it, and that the smaller engineering groups can make an important contribution to this process. In our view no creative group, and no capable individual within such a group, should be denied support because it is small.

Mechanical engineering is so broad in scope that there are many different approaches which require a different viewpoint, different talents, and different ways of thinking. For even the two largest schools (Toronto and Waterloo) to attempt to become "centres of excellence" in all of the branches of mechanical engineering would be unrealistic. We express the hope that through the voluntary associations of COU and CODE a reasonable degree of rationalization is achieved to ensure that in no important aspect is there neglect, on the one hand, or an undue emphasis on the other. We also suggest that the smaller universities, in recognition of their special abilities and circumstances and with their new and fresh outlook, be encouraged to experiment with new programs and new institutional arrangements.

B. Department of Mechanical Engineering - University of Ottawa

Although the history of the university reaches back well over a hundred years, the work in mechanical engineering was begun less than ten years ago. In 1967 a PhD program was started, but after admitting a few candidates (who are continuing to completion) the program was suspended.

We were impressed by the new physical facilities and the enthusiasm of the faculty. We understood their concern at facing the possibility of a stillborn program which they had obviously planned with care. The staff are valiantly endeavouring to relate their research and direct the work of their students towards the problems of Canada's north. We commend them for this effort. We further believe their qualifications and their facilities are such that a viable PhD program can be established and we recommend that an assessment team be sent there as soon as possible. However, we advise caution: we believe the entire engineering program at Ottawa is just beginning to coalesce; their numbers, staff and students are small; we therefore suggest that the faculty in all engineering departments (Chemical, Civil, Electrical, Mechanical) be asked to work together at the PhD level and that they attempt to give an undesignated PhD degree in engineering. In so recommending, we believe this will create an atmosphere such that a meaningful experience and degree at a very advanced level can be achieved. Such a unified faculty approach to work at the PhD level would be a unique experiment in the entire Canadian system, and one worthy of trial at Ottawa.

Under the existing arrangements there is a good interaction between all of the engineering departments and many other departments of the university at the graduate level; we think this should be continued and strengthened. The commitment of the department to research in areas concerned with the development of the north must, of necessity, be conducted on a broad interdisciplinary front. We note that good ties have been established with federal government agencies concerned with northern development; we believe that in cooperating with these agencies a "functional" rather than a "discipline-oriented" interaction is likely to be successful.

Further, the University of Ottawa is unique in another respect. It has the mandate to provide an educational opportunity for the French-speaking population of Ontario, which numbers some 500,000 people. This is the only bilingual engineering school in Ontario. There is a steady demand and limited supply of bilingual personnel with a high competence in modern engineering technology. We believe Ottawa can develop as the centre to provide such an educational experience and would recommend full encouragement in this direction.

C. University of Toronto - Institute of Aerospace Studies

Quality means different things to different observers. Nevertheless, we are particularly taken by the "steeples of excellence" concept put forward by Dr. F.E. Terman of Stanford University in his studies of engineering education in several states including California, New York and Florida. He states:[10]

> "The quality of the academic program of a college or university is determined primarily by the quality of its faculty and the extent to which this faculty is grouped into 'steeples of excellence'. Faculty quality in turn is a function of knowledge, scholarship, creativity, research competence, ability to communicate and professional leadership. It is significant to note that impressive buildings and expensive equipment are not primary factors in determining quality. While a faculty needs space and equipment to carry on its work, space and equipment do not by themselves produce excellence."

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[10] F.E. Terman and A. Higdon, A Study of Engineering and Engineering Technology Education in Florida, Chancellor's Office, State University System of Florida, Tallahasse, Florida, August, 1971.

A steeple is formed by a group of capable faculty members having closely-related interests. High steeples can be seen at longer distances; thus high steeples have clearer national "visibility". High steeples benefit academic programs in related areas, making it easier to recruit faculty in all fields, and add vigour to the entire institution. It is Terman's claim that a high steeple can be built with as few as five faculty members.

We view U.T.I.A.S. as a high steeple not just in Ontario but in the entire Canadian scene. It was born out of a national need and nurtured in the early years by the Defence Research Board. About 75% of the funds required for support are received from sources outside the University of Toronto. Here is a collection of research engineers and scientists closely linked to the aerospace field but showing versatility by reaching out to other industrial endeavours. They draw their students from across Canada and throughout the world and select their problems on a broad base but still relating themselves directly to the Canadian scene. We view this operation as unique in the Canadian education system and do not visualize similar centres arising elsewhere. As long as they continue to focus their efforts on relevant Canadian needs we advocate continuing a high level of support with the minimum of interference.

D. Metallurgy/Material Science

A good grounding in metallurgy/material science is, in our view, an important segment of a mechanical engineer's education. In each department visited, with the exception of U.T.I.A.S., a sound relationship had been established between solid or continuum mechanics on the one hand and metallurgy/material science on the other. At U.T.I.A.S. we recognized the excellent work being done in search of solutions to material-based aerospace structural problems. However, we believe this work is being carried out without the necessary supporting framework. One man can hardly be expected to make great inroads in this field by himself. We strongly recommend a much closer relationship with the materials personnel working on the main campus.

At the University of Waterloo, on the other hand, the material science group is well integrated into the mechanical engineering program, in fact, it is an integral part of the department. This apparently comes about by design for they constitute the strong support arm for continuum mechanics and production engineering. Their role is vital to these areas and they are admirably discharging their responsibilities. As a consequence, their research has a strong industrial bias. We are intrigued by this effective combination of resources, commend them on this approach and recommend its continuance. We, nevertheless, recognize a similar administrative arrangement might not be appropriate at other universities.

E. Faculty Age Distribution

The age distribution of mechanical engineering faculties in Ontario shows the effects of the hasty buildup. The present faculty, 156, if uniformly distributed in age between say 30 and 65, would have about 4.5 faculty at each age level. The actual distribution is shown in Figure 1. The excess in the age bracket, 32 to 47, shows the hiring spree of the 1960's. This distribution has four bad effects:

1. The present faculty is perhaps of somewhat lesser quality than it might have been as there was not sufficient attention and effort made to attract greater numbers of mature engineers in the age range 45 and over.
2. The present faculty will advance in years with very few replacements. There are only 9 retirements in the next 11 years, whereas at the average rate there should be 49 retirements. This means that a whole generation of good young people will have to be passed by because there will be no openings.
3. As the faculty grows older, they, like everyone else, lose their innovative spark, their drive, and their enthusiasm - in short, they become the "old fogeys". The department thus grows old along with the faculty.
4. As the faculty bulge advances, so does their rank and their salary. Before retirement, the average salary may be 50 to 100% more than at present. Some future administration will suffer under the hiring folly of the past decade. It would have been better to hire as a professor an older engineer from industry at the immediate cost of two young men so that his retirement could relieve the pain of the bulge.

What can now be done? Several things:

1. Whenever someone retires or resigns he should be replaced from the age range best suited to fill the gap.
2. After 15 years, when retirements begin to occur in large numbers, new appointments must be made in part from new graduates and in part from older engineers.

If these steps are not taken (and it will be tempting to hire only the less expensive new graduate) a new bulge will be created with the same bad effects as at present.

Of course, there will probably be some relief from the slow growth of the population in general and the demand for engineering education in particular provided due care is exercised in the hiring of faculty in the future growth periods.

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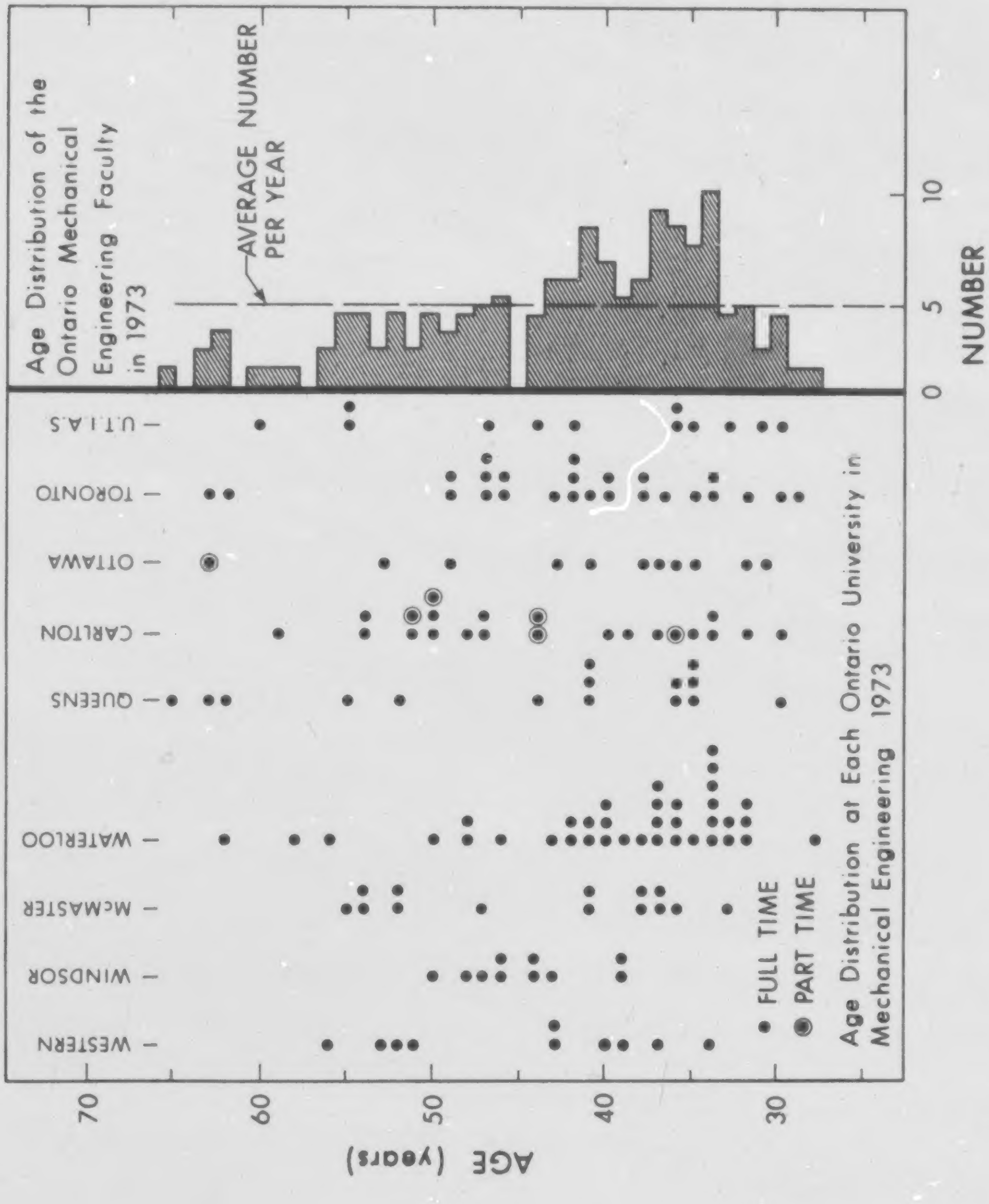

Figure 1

F. Staff Mobility

Here we are concerned not so much with staff exchanges between universities but with the movement of staff between the three major sectors - the universities, industry and government. Such movement is important for the individual, the organization and society as a whole. For the individual it provides an opportunity for improving his career prospects and his satisfaction in his job, a wider experience and fresh stimuli. For the organization it provides opportunities to recruit people of high qualifications and unusual experience with a fresh approach to problems and interdisciplinary experience.

We consider that mobility of staff is essential if we are to develop a competence in all of the functions of engineering at the advanced level. While there are some notable exceptions, we got the impression that many senior staff members have been relatively immobile throughout their careers. At the junior level many staff members of the engineering schools have been recruited directly from their doctoral or post-doctoral studies, without any exposure to the industrial or government sector.

We are aware of the obstacles to mobility: administrative difficulties, misconceptions about the challenge of the work in other sectors, intellectual snobbery, differentials in salaries and working conditions, pension rights and sheer inertia. None is insurmountable once people are convinced of the importance of mobility.

G. Financial Support for Graduate Work

The matter of financial support for graduate work was raised by us at each university visited. In all institutions the pattern of response was similar - the junior staff did not participate in decisions as to how the budget was apportioned between faculties and departments, and therefore did not wish to voice any strong views, whereas at the top of the administrative hierarchy there was concern that any change in the system would reduce the total funds available to that university.

From many discussions on this point we would conclude that the current basic income unit (BIU) rating of 6 for PhD students in engineering is probably not greatly out of line with actual costs. However, in comparison with the smaller units which apply at other degree levels this unit focuses attention on the high cost of advanced degrees and there is a risk that in a financial crisis PhD programs would become the first target for cuts. This might well happen in engineering during an industrial recession, at a time possibly when it would be in the national interest to train more people for leadership in the various fields of technology.

Concern was also expressed with the risk that a high BIU attached to a particular degree will provide a special incentive to the administrators of a university to concentrate more on the growth than the merits of that degree in order to increase the revenue.

We concluded that the present scale of BIUs, which places a premium on the PhD is likely to distort the university education system as a whole and that budget arrangements should leave the individual university free to decide the priorities appropriate to its particular situation.

There is no doubt that a fresh outlook, with the introduction of new courses and a change of emphasis in existing courses, is essential as a continuing process. We suggest that an important, and perhaps the main, stimulus for these should be provided at the graduate level by funds from outside agencies - federal, provincial and industrial - in support of special courses and specific research programs. If the funds from "mission-oriented" government and other agencies were to become readily available the universities could respond more quickly to demands of society which are evolving rapidly, and which may or may not be short-term. The universities could do this without abandoning a commitment to the traditional functions concerned primarily with the advancement of knowledge for its own sake.

We commented earlier (Part IV.A.) on the scale of salaries offered to PhD candidates. We believe that a stimulus to qualified students to enter doctoral programs can be provided to a much greater extent through the selective use of scholarships. Often in the past, initiatives of this kind have had as a primary objective the grooming of the top graduates for staff openings in the universities and government. The emphasis most needed today and in the foreseeable future is in training people for Canadian industry. We think that the voice of industry should be heard more often in discussions of the training of engineers at the graduate level.

Thus we would see the provincial departments responsible for the universities assuming to the maximum extent practicable the "base" load for all of the costs associated with teaching in the broad sense. The cost of research would then be separated from the teaching function and borne separately by the government departments and other institutions, public and private, which require research in support of a mission, or assessed against agencies, such as N.R.C., with a broad mandate to promote scientific research on a national basis. We do not of course suggest that these distinctions are simple, or that black and white answers will be forthcoming.

We also consider that the students who have the required high qualifications to enter the graduate schools and do research should receive substantial aid in the form of scholarships and fellowships from the agencies concerned with promoting research.

VII. RECOMMENDATIONS

1. There should be no assigned quotas for PhDs in mechanical engineering for the Ontario system as a whole nor for the individual institutions.

   (While the capacity of the present system is in the order of 300 PhD candidates we believe, contrary to the projections of the discipline group who predict a slow growth in the PhD population from the present 150 to 180, that because of the changing immigration policy and the known decrease in the undergraduate enrolment there will be a slow, steady decline during the next several years. Emerging market forces could reverse this expected trend. For these reasons we see no foreseeable oversupply but rather an undersupply dictated by the availability of good candidates. It is our firm conviction that by 1978, barring an unforeseeable economic disaster, the supply will fall far short of the demand. Hence there is no present need for large faculties nor facilities. The supply of qualified candidates, the demands of the market place and the competitive forces between institutions is the best guide to the future.)

2. The quality of each of the existing programs in the total system is acceptable.

   (Mechanical engineering by its nature is a highly-diversified discipline. In content, there is a wide range of topics generally embracing three main areas - solid mechanics, fluid mechanics and thermosciences. Each department within the system has adequate coverage in these main areas and has developed a distinctive characteristic depending on its specific resources. The larger departments have a diversity of expertise which permits them to cope with a wide range of interest while the smaller ones have reached out to develop close contacts with industry and government agencies to enhance their resources. Both large and small departments have established excellent research relationships with bioscience departments in the environmental and bioengineering fields. We, therefore, find the PhD program at each university to be acceptable and viable.)

3. Decisions to assign specific research areas to particular departments should be made within the university and not by an outside agency.

   (These decisions are best left to the department itself, which will, in the competitive sense, attempt to get the maximum return from its resources. The basic strength of any department lies with people themselves. We would expect they would, in developing a new or expanded program, consult with their colleagues at other institutions and with granting agencies. However, their research efforts could be made more relevant by a movement away from the classical research areas to research on the phenomena of greater current concern to governments and industry.)

4. The normal mechanical engineering PhD program should contain 1½ years of a broad selection of courses beyond the Baccalaureate.

   (This normally implies 6 full courses or their equivalence. To have a balanced education of maximum value in engineering practice a student needs a broad knowledge to permit problem solving on a broad front and detailed knowledge in depth in some specific problem. The courses should provide breadth while the thesis provides depth. As thesis work becomes redirected more towards problems of current societal and industrial concern, it will become especially important to have and to use the basic methods and material from a broad range of core courses.)

5. PhD graduate work in mechanical engineering at the University of Ottawa should be integrated into a multidiscipline effort in conjunction with the other engineering departments of the faculty to provide the vehicle for a nondesignated graduate degree in engineering.

   (A unified faculty approach to work at the PhD level would be a unique experiment in the Canadian system, and one worthy of trial at Ottawa. If this is accomplished no new mechanical engineering departments or enlargements of the present ones are required during the next five years. The present staff and facilities can handle all the PhDs likely to apply. The real limitation will be the number of good candidates.)

6. Special care should be exercised in the replacement of faculty who retire or resign, to correct the present seriously unbalanced age distribution in the Ontario system, especially in the younger departments.

7. The entire question of financing research and graduate work in the universities of the Ontario system should be re-examined.

   (The encouragement of advanced work by graduated BIUs has had the desired growth effect. Now that the system is mature in size, the Province of Ontario should meet its educational responsibility by providing for basic per capita support about equally at all levels. However, the research support needed at the master's and doctoral levels should, to a major extent, come from research grants and contracts from industry, the federal government and other sources and, when appropriate, the province. The need to obtain research support in a branch of engineering would help keep it relevant, would provide the best environment for the students and would provide a healthy stimulus to the faculties.)

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APPENDIX A

OPENING STATEMENT MADE AT EACH SITE VISIT

Gentlemen:

We meet with you this morning to inform you of the responsibilities we, as a group, have to face in the next several weeks and to seek your response to some of the questions that have been placed before us. In doing so, we wish to clear the air of any suspicion or rumours that may precede or follow us. We ask you to participate freely in the discussions in open forum this morning or, if you wish, later in the day in private or small group sessions. After we leave, ideas may occur to you; please feel free to communicate with any one of the visiting team. We will welcome your thoughts at any time.

Many factors affect our task which is to review the yearly enrolment of some 100 or so PhD mechanical engineering candidates and recommend on the kind, quantity and distribution of these candidates throughout the Ontario system.

Factors affecting graduate student numbers at the PhD level are many. Among them may be included:

1. The response of industry: small companies (and Canada abounds with these) have felt, up to now at least, that highly-educated personnel are an expensive overhead they can ill afford.
2. N.R.C. Industrial Post-Doctoral and Senior Industrial Fellowships are helping to overcome this reticence on the part of industry large and small, hopefully giving rise to an increase in demand for PhD graduates.
3. The funding policy of N.C.R. requiring fellowship holders to be Canadian citizens or landed immigrants tends to reduce the supply.
4. Attitude of professors when interpreting "Assistants" on the N.R.C. grant forms. Some professors interpret this to mean they do not have to support graduate students but rather to hire professional help to assist them with their research. This negates one of the main purposes of research at a university and again reduces the intake of PhD candidates. It is known that some qualified students are being refused because of this practice.
5. The attitude of society to engineering and the physical sciences is one of suspicion. We are the anti-heroes. War and the degradation of our environment are associated with engineering and the sciences. Students have been "turned off" and they are slow to return.
6. The attitude of society in general, and governments in particular, to research is likewise one of suspicion. Prior to 1960, most engineering faculties in Canadian universities were excellent undergraduate institutions, teaching loads were 16-18 hours per week,

research was carried on mainly on a personal basis. In the 1960's all this changed. Every university, with public encouragement, expanded its research programs; teaching loads were reduced to 8-10 hours per week. It is now estimated that the teaching and research costs are nearly equal. Governments seem to wish to redistribute this cost to something like 60-40 or even 70-30. With the support of the general public, in view of the high cost of research space, the governments have severely curtailed building expansion. What is research, where does it fit in, who should do it, are questions we all must struggle with. In this regard, the Corry Bonneau report, "Quest for an Optimum", is worth reading.

You are aware this study is a follow-up to the report Ring of Iron and the CODE response to that report. Our task is very specific. It is to pick up where the report, with reference to PhD studies, left off. ACAP is conducting a general study of PhD programs in the Ontario system; we are but a narrow segment of that broad study. Our task is to review and recommend on the PhD program in mechanical engineering. Other teams will consider the many other disciplines under review and our report will come together with theirs from which a combined report will emerge.

We understand that the total number of PhD candidates in engineering has some general agreement and is in the order of 450. The main areas of dispute between the Ring of Iron and the CODE reply were:

1. the rate or year at which this number would be achieved;
2. the distribution of candidates among the universities;
3. the designation of programs at various universities;
4. the viability of PhD programs at certain universities;
5. the various cost factors involved in PhD work.

With this as background, we have been asked to:

1. visit each university with a PhD program in mechanical engineering, review its background and capability.
2. report on the adequacy of the present state of doctoral work, including
   (a) coverage and specialities, extent of activity;
   (b) faculty quality and quantity;
   (c) nature of the programs offered;
   (d) enrolment sizes and distribution among universities and divisions;
   (e) quality of the student body;
   (f) relationship with related disciplines and the profession;
   (g) physical facilities.

[We cannot condemn or curtail but may ask for a review.]

3. our recommendations are to cover five years, 1973-78 on:
   (a) desirable doctoral programs in Ontario;
   (b) desirable enrolments, year by year, taking into account the available market;
   (c) distribution amongst universities for various programs;
   (d) distribution of enrolments amongst the universities and desirable ranges of enrolment.
4. we can consult far and wide - universities, industries, government, etc.

We have not begun to face all these issues but are searching. We seek your thoughts on such questions as:

1. How do you view a quota system? In today's world, do you think one is required? Are the numbers generous? Do the present conditions regulate sufficiently so a quota is not required?
2. Failing a rigid quota system, how would you view a provincial-wide pool of engineering PhDs with a quota on the pool? Students would be admitted on the basis of excellence and would choose their schools and programs.
3. On a narrow basis (same as above but for mechanical engineers only)?
4. If you are not prepared to have restraints such as are suggested, how would you meet the budget reductions likely to be imposed?
5. Would you accept a variation of PhD support between universities
   (a) by eliminating or reducing the premium or differential paid for PhD students? Maintain total income to engineering the same but change the base 2 or 3 Units for engineers up to and including master's level and some schools because of program and considered excellence be given a premium of 1 Unit for each PhD candidate; other schools would have PhD candidates if they so chose but without the premium?

Finally, may we thank you for the cooperation we have received. You have prepared many statistics for our use. We have intruded into your summer plans. We may even come back for more data and assistance. Our specific report will be reviewed by the Committee of Department Chairmen for errors of fact before it is submitted in its final report. It will not however come to each department for scrutiny. Thank you for your help. We welcome your questions and suggestions.

ADDENDUM

REPORT OF THE
MECHANICAL ENGINEERING CONSULTANTS

THE ADVISORY COMMITTEE ON ACADEMIC PLANNING
ONTARIO COUNCIL ON GRADUATE STUDIES

H.W. Emmons, G. Ford, R.D. Hiscocks and S.G. Mason

17 May, 1974

REPORT OF THE
MECHANICAL ENGINEERING CONSULTANTS
TO
THE ADVISORY COMMITTEE ON ACADEMIC PLANNING
ONTARIO COUNCIL ON GRADUATE STUDIES

ADDENDUM

In the original report we urged that the Departments of Mechanical Engineering of the Ontario universities consider a redirection of their efforts at the graduate level toward studies of important problems which underlie mechanical engineering practice. We emphasized the importance of the leadership role of the university in the full use of both rational analysis and empiricism in engineering. The purpose of this addendum is to explain in greater detail the reasoning which led to that recommendation and to suggest ways in which it could be implemented.

The picture today, as we see it following our visits to nine departments, is described in general terms in the original report. The work at the graduate level in the majority of departments is strongly oriented toward theory and analysis. Within the three fields basic to the discipline - applied mechanics, fluid mechanics and thermodynamics - the areas of specialization selected for research vary from time to time in all of the departments, depending on the interests and capabilities of the staff and students. In the process of selection, the projects which are deemed to be the most suitable have been assessed within a competitive system dependent upon critical peer judgements of the capabilities of the scientist and the quality of his work. Generous financial support for most of these projects has been provided through funding by the NRC, usually in the form of operating grants.

In large measure the current emphasis on the classical problems of engineering science is the outcome of policies which were introduced in the post-sputnik era to meet the unprecedented demand for engineers trained in the techniques of advanced analysis. In the light of the record to date it would be difficult to argue that these policies have been a complete failure - the research which was used as the vehicle to train engineers has contributed to the knowledge of the physical sciences, and, judged by the usual criteria - publications in refereed journals, contributions to symposia, the quality of student theses - the standards of accomplishment have compared favourably with the 'norms' accepted by the scientific community. For two decades the graduates who were the products of this system experienced no difficulties in finding employment in the universities and in certain fields of advanced technology, notably the aerospace industries.

Not all of the schools we visited have contributed equally to this record, some are much newer than others, and some are much stronger than others. Nevertheless we did not feel that, to the extent that we could assess them in a short visit, individual differences between departments, or any possible shortcomings, were outstanding. Accordingly we reached the conclusion that all of the departments we visited have sufficient faculty capable of offering the essential core courses and of supervising the 'traditional' type of thesis through the entire graduate spectrum.

There is little doubt that the traditional type of training will equip those who have the ability, and the motivation, for creative careers in basic research, in theory and conceptualization, and in technical problem solving. However, we very seriously question whether this is sufficient in the advanced training of all mechanical engineers. In our society today there is an urgent requirement for entrepreneurs who are not only well informed in the basic sciences but, in addition, possess a wide range of interests extending from the technical to business and management.

From the problems we face today and the growth in career opportunities, it is clear that there will be a substantial demand in the future for engineers with advanced training in breadth as well as depth. These will be qualified in certain functions of engineering, as well as the basic technical ingredients, they will have acquired the essential training in mechanical design, or production engineering for example. A short time after graduation the individual with advanced training may be called upon to function as a project engineer. In that capacity he may be expected to provide leadership and motivation to a group responsible for a major technological undertaking. He will be responsible for planning and organizing the work, meeting deadlines, handling budgets and costly resources, ensuring that the proper coordination exists between the team members and that the project moves forward expeditiously.

The notion that the functions of engineering can be learned 'on the job' has produced distress and disenchantment in young graduates and employers alike. Each function - research, design, production, systems planning - requires a different approach, viewpoints, talents and ways of thinking and it is essential for the student to acquire a deep understanding of certain of these - and to be able to distinguish between others - before he is launched upon a career in engineering. The importance of preparation identified with the functions of engineering appears to be better understood in countries where the 'technological' universities have deep roots - and the tendency of our firms to seek to recruit 'production engineers', for example, from outside Canada is one of the results.

It is to be stressed that we are not suggesting that the emphasis in the education of mechanical engineers should shift from theory and analysis with some synthesis to an utterly empirical attack or a complete preoccupation with hardware. The primary need, as we see it, is to expand university research into the basics of the more relevant, less classical problems. We would favour a greater emphasis on the formation of project teams to undertake relatively simple design problems, but we would strongly oppose any suggestion to carry this to the stage of the detailed design, development and prototype manufacture of complex structures or mechanisms. Undertakings of this kind are best left to industry and the way for the advanced student to gain good experience with these is through cooperative programmes which include industry as an equal partner with the university.

We do not pretend that it will be easy for the departments of the universities to strike a balance between the traditional approach, which has the support of a wealth of experience, and the strident and often short-sighted demands for 'practicality' or 'relevance'. A stronger dialogue between university staff and the employers of qualified engineers would help. If we look at the problems before us today in the fields of energy, transportation, or the environment, it is apparent that there are many gaps in the knowledge which should be attacked systematically to provide the basic design data which is essential to advances in engineering and advances generally in technology on the broad front. We look to the Departments of Mechanical Engineering in the Ontario system to lead the attack on these areas of concern. Some have already begun this work.

We have stressed the importance we attach to the design function. With few exceptions the work in this area which we examined was disappointing. Usually the approach was intuitive, plus 'handbook'. Rarely did we find an appreciation of the place of science in design. In the outcome there is a tendency to regard the role of the professor who teaches design as different, perhaps even inferior. He has difficulties in attracting research grants, with implications that are all too familiar.

As each function of mechanical engineering is based on a different philosophy and approach to a problem, a wide variety of choices is open to the various departments, and even the largest department cannot cover all of the fields. Conversely, even the smallest group we saw is capable of making a useful contribution, provided the group is not working in isolation from other groups in the university, and the area for a concentrated effort is selected with care.

Some examples of steps which would, in our opinion, redirect some of the current work toward innovative studies of more urgent problems which arise in mechanical engineering practice are suggested in the following paragraphs. They are based largely upon initiatives which have already been undertaken or proposed in the five year programme of the various departments.

CARLETON UNIVERSITY

In the general field of energy production the gas turbine is of sufficient importance to justify, in addition to the teaching of engineering fundamentals, a concentrated undertaking at the graduate level in one Ontario university. Carleton has the staff nucleus which has recently been strengthened by several very good people in this field, it can call upon the specialists in the government laboratories, and it has access to extensive test facilities which are not available elsewhere in Canada. Accordingly we would recommend this work for continued support.

The work in this department on studies of heat flow and fluid mechanics as they relate to nuclear reactor technology is appropriate, and it is noted that the group at Carleton is working in close cooperation with CGE and AECL.

In summary it would be desirable, we believe, to concentrate on the development of a strong competence in the field of gas turbine technology. Many of the staff engaged in other activities could, we believe, direct their efforts in this direction.

For the present we would treat the others as adjunct fields and encourage them to build up more slowly. The object would be to exploit these other fields at a later date, depending on the pace of development of the gas turbine field.

McMASTER UNIVERSITY

The laboratories are well equipped and the research work by individual professors in the 'core' areas of mechanics, thermodynamics, fluid mechanics, is of good quality.

The emphasis on Engineering Design in this department is stronger than at most universities and has received wide recognition. We have stressed the importance of design as one of the basic functions of engineering and we would like to see this work receive even more support in this university.

Manufacturing Engineering is recognized by this university as a programme with a high priority and a strong team is engaged in metal cutting and metal forming research. It is receiving substantial financial support from the university and from at least one federal agency. Although the programme is at an early stage there is no doubt about its 'relevance' to the advanced technological problems of industry and of the willingness of industry to participate. The requests from the firms for research under contract is growing rapidly. An Advisory Board, comprised of leading industrialists in the Hamilton area, has been formed. Good cooperation and a reasonable degree of coordination exists with other university staff working in the field of manufacturing engineering at Waterloo and Queen's.

In our original report we suggested a stronger theoretical base to guide the experimental work, to assist in the interpretation of the results, and to provide a better understanding of the phenomena encountered in metalworking research. For the student who is 'theoretically inclined' this would imply additional opportunities for study.

We would also suggest that consideration be given to the possibility of making manufacturing engineering the focal point of work in this department, and that whenever practicable the orientation of other work be changed to conform with it and to provide greater unity of effort. It is to be hoped that the practice of cross-appointments and the interaction of this work with other disciplines within the university - which has already begun in some instances - will grow to the point where the programme will become a highly significant, if not a dominant, attraction to students planning a career in manufacturing, production engineering, or a related field. There is confidence that the graduates of this course will be in great demand.

University of Ottawa

Our earlier report contains a recommendation for the development of a joint programme in conjunction with other engineering departments of this university at the graduate level. We continue to hold this view. It was based upon the fact that the Department of Mechanical Engineering is new and relatively small. The average age of the staff is also young, 80% of the staff are under 45. The orientation is rather heavily slanted to the academic, 70% of the staff have very limited industrial experience.

We would have serious reservations about a number of the projects proposed for research at the graduate level in this department - the work done by industry on the performance and lubrication of two cycle engines, for example, leaves little scope for future development in a university laboratory. On the other hand we would strongly endorse the proposal to perform research which would lead to a better understanding of the basic science and the problems underlying operations in cold climates. Problems identified with, but by no means limited to, permafrost, materials, lubricants and corrosion, for example. To accomplish this will require strong leadership, enthusiasm and a close association with some of the current developmental activities in the North. We consider that a multitude of problems of this nature will arise which are worthy of work at the graduate level and that, as stated in our previous report, they will not be confined exclusively to mechanical engineering but generally will be interdisciplinary in nature.

The growing cooperation between this faculty and that of Carleton University and various federal government agencies in sharing the expertise of the staff and the physical facilities is to be commended.

QUEEN'S UNIVERSITY

It was the impression of the consultants that the groups concerned with heat transfer and fluid mechanics were working rather independently of one another and that some guiding effort toward a more limited goal, which would provide a target for many of the activities of the staff, would be desirable.

Rather similar conclusions applied to the work of the Institute of Guided Ground Transport. The activities of the Institute include work on track and tracked vehicle dynamics, vibration, stability and control, and the design and operation of vehicle control systems. Therefore a good case can be made for integrating the work of the Institute with a number of the projects currently underway in the Systems and the Applied Dynamics Groups. Other groups in mechanical engineering working in the related fields of heat transfer, fluid mechanics and propulsion could also make an important contribution. There is considerable scope in this work for the constructive participation of other departments such as Civil Engineering and Economics. The feasibility of making the Institute the focal point of these activities, of course, depends upon the support which can be provided within as well as external to the university. Such an integration would provide facilities, a common sense of purpose for the staff and students, and, in the long term, afford the university the opportunity to provide a 'centre of strength' in railroad engineering which has become an urgent national requirement. None of this is possible without the enthusiastic support and the guidance of the senior administration of the university.

UNIVERSITY OF TORONTO

We would not attempt any detailed assessment of the extremely broad spectrum of the work in this department. It is accepted that the staff are generally of high calibre, the students are selected with care and a significant level of activity has been achieved within many areas of study.

Earlier in this report we emphasized that even the largest departments cannot provide adequate training in all of the functions and fields of mechanical engineering. Accordingly we feel that a greater concentration of effort within this department would be more productive and would suggest fundamental areas of study and applications appropriate to an important, continuing problem area of engineering today. The talents and resources available to this department are great and perhaps could focus on a major problem of national concern, such as we find in the field of energy.

UTIAS

Many changes have occurred since the Institute was first created and achieved its initial growth. At that time there was a burgeoning aircraft industry in Canada, a strong defence interest in gas dynamics and highspeed flight, and the prospect of considerable aerospace activity by the government and a number of Canadian firms. Substantial support for the Institute was received from defence agencies in Canada and the U.S.A. It was an accepted fact that many graduates would emigrate to the United States.

A genuine effort has been made to shift the emphasis in the work of the students to fields of interest which are likely to be of benefit to Canada - the aerodynamics of buildings, long-term noise control, the dynamics of vehicles, are examples. There is general agreement on the need to be highly selective within the broad spectrum of the expertise of the staff in plasma science, low density gas dynamics, subsonic aerodynamics, flight dynamics, shockwave phenomena and noise. There is also little doubt that the work in the field of structures and materials would benefit from a strong interaction with the work in related fields on the main campus of this university.

It is encouraging to observe that the cooperation between the UTIAS and main campus staff is growing in a very practical way and is not restricted to the engineering disciplines. Indeed, our recommendations for the Department of Mechanical Engineering have implications for UTIAS also, for the two departments, working under the same umbrella, could develop a capability in a selected field - such as alternate sources of energy - which would constitute a strong national asset.

UNIVERSITY OF WATERLOO

We would again stress that no university is capable of covering the whole spectrum of engineering practice. At Waterloo the spectrum is so broad that depth in any single area is limited compared with what could be accomplished if attention were focussed on a more limited area of specialization. Most of the independent efforts with very little reorientation could be brought together in a programme of teaching and research which would be very strong.

The work in the field of manufacturing and production technology might well be used to provide the required focus. Waterloo is located in the centre of a large concentration of light manufacturing industries, and, as a result of a cooperative programme (alternate terms in industry and university) of undergraduate teaching and the consultative activities of the staff, has established a rapport with many firms. It would therefore appear logical to devote considerable attention to the work in Production and Automation. The current effort at the graduate level in Production and Automation is of satisfactory quality, but the level of effort is small in relation to the needs of this country and to the capability of the department.

The staff at Waterloo expressed concern that during the past five years the number of full-time candidates for the PhD in Mechanical Engineering has been steadily diminishing, whereas the demand is increasing. No doubt there will be a change when the word gets around of the number of job offers the graduates are receiving - at least in Production and Automation. But some 'push' on the part of the university, in recognition of the 'pull' that has developed in industry, would be timely, and it might turn out that in contrast to the more traditional topics the obvious 'relevance' of production, automation, and related areas involving design, would have a strong appeal to the students.

UNIVERSITY OF WESTERN ONTARIO

The work at Western in the precise measurement of the thermo-physical properties of heavy water is of high scientific quality and has received international recognition. It is also of great interest to AECL and has received financial support from that and other government agencies. We understand that a programme concerned with new and improved methods of heavy water production is under consideration. This is to be encouraged, provided the current work can be extended or redirected to place the emphasis, not so much on precise measurement, but more on more innovative methods of producing heavy water and on a better understanding of the basic phenomena underlying the production.

The principal effort in Applied Mechanics has been in the field of noise and acoustic research. Although it is not identical, there is a close parallel with the work in the same field at Windsor. While the need for research in this field will continue to grow it may be very difficult for this group to 'compete' with the staff level of excellence and facilities available for advanced theoretical work which have been developed over the years at other institutions, such as UTIAS. The need for 'Applied Acousticians' with a good training in the basics of the subject, who will design noise measuring instruments, advise government agencies on acceptable noise levels, and participate in the design of buildings, is urgent. Therefore we feel that the current emphasis at Western in the training of students up to the master's level in this field is highly commendable. On the other hand we believe that, pending a stronger base on theoretical work, it may be desirable to reserve undertakings at the PhD level in acoustics research for an exceptional opportunity, such as that which would be provided by an unusually talented student, for example.

UNIVERSITY OF WINDSOR

In the Department of Mechanical Engineering the main groups - thermo-fluids, noise and vibration, experimental stress analysis and industrial engineering - interact with each other and with the Chemical, Civil and Industrial Engineering Departments to a high degree. From the standpoint of developing a strong engineering school in the professional sense this interaction is highly desirable. Industrial Engineering, which began in the Mechanical Department, has developed into a separate department, and, at the graduate level, maintains a good working arrangement with the mechanical groups.

Currently the thermo-fluids group has the largest participation by staff and students. In our opinion the projected number of PhD students to be attached to this group is unlikely to be obtained, and we consider that the proposed ratio of PhD to master's students is unrealistic.

In the work of the group in Sound and Vibration the emphasis on machinery and vehicle noise is well chosen. It can be used to produce qualified people, and research results of direct use. The demand for people well versed in this field to the master's level will be greatly in excess of the demand for PhD's, and one wonders why the forward projection is for two or three students in each category. A concentration on the master's level of training, at least during the early stages of the development of the group, pending a strengthening of the theoretical background, would appear to be more desirable.

In the Experimental Stress Analysis group a good start has been made and further work to exploit other phenomena, such as interferometry, is to be encouraged. We rather question whether the field of experimental stress analysis, of itself, is broad enough to justify a PhD programme in the absence of a complementary activity in applied mechanics, electrical/electronics technology, instrumentation (such as holography) etc.

At this University the interdisciplinary ties within Engineering are strong, and it has been suggested that the work in experimental stress analysis and in acoustics would be strengthened if both groups were to continue to work closely with Industrial Engineering.

17 May, 1974.

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APPENDIX B

DISCIPLINE GROUP RESPONSE

Note that this response was prepared before the consultants wrote the addendum to their report.

RESPONSE OF MECHANICAL ENGINEERING DISCIPLINE GROUP

to

REPORT OF MECHANICAL ENGINEERING CONSULTANTS

OCTOBER 1973

The final report of the mechanical engineering ACAP consultants was carefully studied and unanimously endorsed by the mechanical engineering discipline group (MEDG) on November 9, 1973.

The MEDG after careful consideration and detailed discussions reached the conclusion that the perspective, impeccable reputation, and international stature of the ACAP consultants give complete credibility and authority to the value judgements and recommendations contained in the consultants' report. The MEDG considers that the recommendations of the ACAP consultants being general in nature are valid for all of the engineering disciplines. The strength of the report therefore lies in the very nature and the generality of the recommendations. We as a group (MEDG) look forward therefore to continuing the dialogue between the Coordinating Task Force, CODE and COU in order to ensure the implementation of the consultants' report.

The major and perhaps most significant conclusion reached by the ACAP consultants was that the quality of the existing programs in the total system is both viable and acceptable. Though the consultants challenge the departments to redirect Ph.D. thesis research toward innovative studies on problems currently relevant to industry and society, they make the unequivocal statement "We have no serious reservations about the extent of coverage in the present programs certainly not to the point of suggesting the termination of any". In effect it is the considered judgement of the ACAP consultants that each department possesses the intellectual and physical resources to ensure good Ph.D. study on "mission oriented research" and that there is a place for the small and large departments.

By reviewing the available numerical data and statistics the ACAP consultants concluded that the so-called under-employment and over-supply situation for mechanical engineering Ph.D's. does not exist. They went on to observe "that due to emerging immigration policies the supply of good

Ph.D. candidates by 1978 will fall far short of demand". They stressed that, in order to effectively combat the erroneous and negative views which frequently appear in the press, engineering faculties should maintain up-to-date historical records of the careers of Ph.D. graduates and better information on job opportunities. The MEDG in turn considers that a high level fellowship and scholarship program aimed at the "good students" could narrow the gap between supply and demand.

The consultants have pinpointed the two challenges which we face. First, industry must be kept aware of the value of Ph.D. graduates, and second, competent students must be informed of the importance and benefit of advanced studies. Two of their recommendations are aimed at meeting these challenges, namely:

a) A Ph.D. program should contain six rather broad and generalized courses beyond the Baccalaureate comprising of mechanics, solid mechanics, fluid mechanics, transport phenomena, thermodynamics and modern applied mathematics.

b) By consulting with colleagues at other institutions and with granting agencies, individual research efforts and graduate research theses could be made more relevant by a movement toward research on the phenomena of greater concern to governments and industry.

The above concepts of a broad based academic program and a thesis research program were accepted without reservation by the MEDG.

Because of the present financial constraints the MEDG, though agreeing with the findings of the consultants about the desirability of hiring both mature engineers (in the age range of 45) and young engineers with promise (30 years or less), considers that it will take some time before this can be implemented. Perhaps a partial solution to the age distribution problem would be to regularize in a more systematic manner the movement of staff between the universities, industries and government. The universities, the provincial government and the National Research Council could be of assistance by removing obstacles currently associated with tenure, pension rights, salary differentials and working conditions.

The last recommendation about the BIU dilemma has been the subject of many diverse ACAP reports. The concept of more or less equal basic per capita support at all levels appears to be valid but it is equally apparent that a transition period (measured in years) would be required if their recommendation is accepted to prevent serious dislocation.

Respectfully submitted

for E.S. Nowak

E.S. Nowak, P.Eng.
Chairman, Mechanical Engineering
Discipline Group

ESN:em
7 December 1973

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APPENDIX C

UNIVERSITY COMMENTS

Comments appear from Carleton, McMaster, Ottawa, Queen's, Toronto, Waterloo, Western Ontario and Windsor.

Note that these responses (except that on page C-34) were prepared before the consultants wrote the addendum to their report.

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CARLETON UNIVERSITY

RESPONSE TO FOUR ACAP ASSESSMENTS ON ENGINEERING

Introduction

Carleton takes the view that groups of disciplines should be evaluated before a clear picture of the situation within a single discipline can be obtained. Reports on any one component considered in isolation could lead to an erroneous judgement and unwise and precipitate action. Three consultants' final assessment reports have now been received for engineering disciplines in which Carleton is actively involved: Civil Engineering, Electrical Engineering, and Mechanical and Aeronautical Engineering. A fourth report deals with Metallurgical and Materials Engineering, of less direct concern to Carleton, while a fifth report, not yet received, will deal with Chemical Engineering, a discipline not represented at Carleton.

This response will address itself to the four reports which have been received and examined to date. We may wish to add further comments when the fifth report has been studied.

We sense a good deal of unanimity on a number of fundamental questions among the fifteen consultants involved in the four reports so far received, a communality of viewpoint which we share and endorse. We believe that Engineering has been most fortunate in having the assessments carried out by a group of consultants whose international stature, valued judgement and perspective give authority and credibility to their studies and reports. In general then we accept their findings and subscribe to their recommendations with only a few exceptions to be noted later.

In this response we shall deal first with those matters which we believe to be basic and general in nature and leave until the end our views on specific points raised in individual reports.

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Matters of a Fundamental or General Nature

1) Control of Student Numbers:

The four reports are unanimous in their opinion that previous estimates of the demand for engineers with doctoral degrees, notably those in the Lapp Report of 1970 and the report for CEMC of 1973, have erred seriously on the low side. They point out that there is no evidence of difficulty in obtaining jobs by students close to graduation, nor do they foresee difficulties in the future except for those which normally occur in highly specialized areas.

The consultants reject the notion of quotas applied to departments to control student numbers, in part because the demand seems likely to exceed the supply than the reverse, making quotas unnecessary, but in the main because they feel that other means of control are to be preferred. The report on Electrical Engineering puts it this way: "The number of doctorates granted in electrical engineering (should) be determined by:

(i) availability of qualified students

(ii) maintenance of adequate standards by the universities, and

(iii) the existing capacity (staff and facilities) of the universities for giving adequate training." The Mechanical consultants refer to emerging natural controls and go on to say: "We would wish the resources of the present system, which are predicated principally on undergraduate requirements, the market demands, the quality of the programme and the good judgement of the departments to determine the total number within the system."

Carleton subscribes fully to these views. We believe that rather than through centrally imposed quotas or limitations the universities individually should control numbers by restricting admission to students showing high promise and by maintaining adquate standards. The latter together with the market demand will provide an adequate control. We would be prepared to support the development and adoption of an evaluation scheme, such as the scholastic index used at Carleton, which can be applied across all disciplines and which could be used in the monitoring of admission standards which we believe should be a matter between a university and OCGS. We believe,

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however, that the interpretation of these standards for individual student cases should be left to the informed judgement of the university concerned.

2) Quality of Existing Programmes, Suggestions for Change:

From their comments on the quality of the Ph.D. programmes for the system generally, it is clear that the consultants believe it to be quite acceptable. The Civil consultants point out that "the system provides a good quality coverage of the field and specialties without undue overlap on a regional basis." Comments on individual universities draw attention to departures from the norm in both directions.

A common theme running through the reports is the need for greater flexibility in the future. The Metallurgical and Materials consultants state it this way: "As Canadian industry becomes more sophisticated and has to rely on more advanced technologies, it will have to learn how to fully utilize the talents and skills of Ph.D. graduates and the universities will have to learn how to develop Ph.D. programmes which produce imaginative engineers capable of responding to these new opportunities." These consultants also recommend that programmes be so designed as to permit graduates from other specialties to change specialties as they commence Ph.D. work.

The consultants also show a degree of consistency regarding the need to shift the emphasis in Ph.D. programmes to meet the situation of the seventies. The Electrical consultants state it this way: "The education of Ph.D. students in areas of national need is a more efficient use of resources than is a random choice of fields followed by a period of retraining." In relating it to their field, the Civil consultants state that there should be "less stress on traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation." The Mechanical consultants recommend a greater emphasis on production engineering and design.

Close contact between universities and industry is felt to be important by all the consultants and individual universities have been singled out for commendation where this contact is regarded as exemplary while others have been asked to improve in this respect.

Once again Carleton accepts the findings of the consultants on the quality of the existing programmes and their views on the nature of Ph.D. programmes required for the immediate future. We feel that we have already

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made considerable progress toward achieving the desirable objectives set out by the consultants and that we have received adequate recognition for this in their reports.

3) Critical Size:

The Engineering consultants are far less concerned about the concept of critical size than the consultants who carried out some of the earlier planning assessments, and show as much concern for the disadvantages of "bigness" as of "smallness." The Engineering consultants place their primary emphasis on the quality of the student and of the faculty rather than on size, a view which we heartily endorse.

The Mechanical consultants take the strongest stand against the notion of critical size. While admitting the advantages enjoyed by a large group, they go on to express their view that "a drawback to the large group is the difficulty of adapting to change" and further that "the groups in the smaller departments often displayed an original point of view and a willingness to adapt to change that was not apparent in the larger and longer established departments." They found more cross linkages between departments and a greater tendency to establish outside contacts with government and industry in the smaller faculties. They conclude: "In our view no creative group, and no capable individual within such a group should be denied support because it is small." The Civil consultants echo these views: "Size is not a sufficient criterion for judging whether a school can offer a Ph.D. programme" and also "there is no a priori reason why a small school cannot provide as satisfactory an environment for the student as a large school."

The Electrical and Metallurgical and Materials consultants are not as definite on the matter of critical size as the Civil and Mechanical consultants. The Electrical consultants felt that a desirable size for a department fell in the range from 10 to 20 faculty with from 10 to 20 students enrolled but expressed the view that "high standards of excellence with emphasis on quality rather than quantity will pay off in the long run." The Metallurgical and Materials consultants draw attention to the contrast between the British approach to Ph.D. education centered around the thesis and requiring only one good faculty member and the American view that a department needs to be sufficiently large to provide a proper range of

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courses because of the importance given to course work in the American approach. The consultants themselves took the position that students should be taught by members of the basic science departments as well as by Engineering faculty members and that the critical size of the core depends a great deal on the strengths in related disciplines. The latter factor seems to have been ignored by some of the consultants who assessed the non-Engineering disciplines.

As indicated above, Carleton is fully in agreement with the position on critical size taken by the Engineering consultants and does not support the views of the Chemistry or Economics consultants nor ACAP's views on this matter.

4) Proportion of Foreign Students:

All four of the reports under review make reference to the enrolment of foreign students in the graduate programmes at Ontario Universities.

The Electrical consultants noted that the percentage of doctoral students with first degrees from Canadian universities was consistently in the range from 47 to 51 over the past five years. They believe an ideal mix should involve students with a variety of backgrounds coming from various universities and should include some students from foreign countries. The latter they feel should be in the minority and they suggest 25% as an appropriate proportion. The Civil consultants expressed concern also at the low percentage of full-time Ph.D. students who had obtained their first degree in Canada but remarked also that the percentage was much higher for part-time students and suggested that part-time studies should be encouraged.

The Mechanical consultants, while noting a similar proportion of non-Canadian first degree students to those mentioned above concluded that we cannot count on Canadian undergraduate schools to provide candidates in sufficient numbers and that we must continue to rely on students from abroad. The latter would likely decrease in number in the future due to recent policy changes with respect to immigration and financial support for students without landed immigrant status. They suggest that support for such students should come from appropriate federal agencies such as CIDA.

The Metallurgical and Materials consultants find that "Canadian industry unable to fill its vacancies with Canadian graduates of Canadian

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origin has preferred to import graduates from British or Australian origin rather than employ Canadians of Asian origin." They recommend an intensification of efforts to recruit a larger proportion of Ph.D. students from the graduates of Canadian universities.

Carleton is in agreement with the consultants concerning the desirability of having a mix of students from different universities in Canada and from foreign countries and in having a reasonable balance between Canadian and non-Canadian first degree holders. The problem of foreign students is usually expressed as one of controlling their number. We believe that the recent immigration and financial restrictions imposed on this group is likely to overshoot the mark and the problem in the future may well be one of too few rather than too many foreign students. A more serious problem is that of too few graduates of Canadian schools embarking on Ph.D. work.

Comments on Some Specific Matters

In this section we wish to deal with some specific issues raised in individual assessment reports.

1) Civil Engineering Doctoral Planning Assessment:

The references to Carleton University throughout this report are generally favourable and on the whole we like their conclusions and recommendations. There are, however, one or two points we wish to question.

In Recommendation 3 the consultants suggest "there is a case for more consistent requirement of acceptance for Ph.D. students between universities." We are uncertain as to the meaning of this since it is not discussed in the body of the report. We have expressed the view earlier that there should be a system, such as Carleton's scholastic index, for evaluating students across all disciplines, and that OCGS might monitor standards of admission generally. We do not see the need for an external person on acceptance committees but continue to support the position that there should be external examiners on thesis committees.

We cannot accept the proposal in Recommendation 5 concerning the collapsing of the Ph.D. B.I.U.'s into the undergraduate B.I.U.'s although we can support the objective. We believe that a major re-examination of the

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formula for providing operating funds to the universities is called for, not just minor adjustments to B.I.U. weightings.

We do not see the necessity for the further proliferation of degree designations which would result from the introduction of the Doctor of Engineering Degree included in Recommendation 12. We support fully the consultants' concept of a range of possibilities for a doctoral thesis, from the mathematical or theoretical at one end to the design or application-orientated at the other end, but we believe the requirements for the Ph.D. should be flexible enough to permit this as is the case at Carleton.

2) Report on Doctoral Programmes in Electrical Engineering in Ontario Universities.

For the purposes of assessment and reporting, the consultants have combined Carleton's departments of Electronics and Materials Engineering and Systems Engineering under the discipline title of 'Electrical Engineering.' Their comments, conclusions and recommendations apply uniformly to our two departments. We regard this report as a highly competent and thorough piece of work. The analysis in the earlier sections prior to the evaluation of departments gives to the whole a degree of credibility that is probably unique in such reports.

Carleton University has received a uniformly favourable assessment in Electrical Engineering. The Ph.D. programmes in both departments are considered to be "strong." The interaction of Carleton with laboratories and firms in the Ottawa area is described as a "model" while our programmes are praised as having "unusually high contemporary relevance."

We intend to pursue our proposed five-year plan for the graduate programme in Electrical Engineering; we believe that our present organization into the two departments of Electronics and Materials Engineering and Systems Engineering is the most appropriate and effective for our purposes and intend to maintain this organization.

We have noted the general recommendation that only students showing high promise for graduate work should be accepted into the Ph.D. programme. We endorse this recommendation.

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We plan to aim for the small growth in graduate student numbers proposed in the five-year plan, but note that in the consultants' view this growth is modest. We shall allow ourselves to be responsive to the applications which we receive from well-qualified students. We expect that our growth will be limited to a natural and non-excessive rate by the limited availability of good applicants.

We believe that it is possible to increase the scale and effectiveness of our associations with laboratories and firms in the Ottawa area and shall endeavour to exploit further such interactions.

The recommendation that greater use be made of graduate courses given at the University of Ottawa is accepted. The establishment of a close working relationship over the last two-year period has made the sharing of course offerings and facilities a natural outcome which it is intended to exploit.

We accept the report of the ACAP consultants without reservation. We consider the assessment to have been fairly and thoroughly done and believe that the report as a whole will be of considerable benefit to the Electrical Engineering profession in Ontario and Canada.

3) Report of the Mechanical Engineering Consultants:

We accept the ACAP consultants' report on Mechanical (and Aeronautical) Engineering without reservation. We consider it to be a valuable, authoritative, well reasoned document. The report is thoroughly credible because of the competence and international stature of the consultant team and the excellent overview they provide.

We accept the consultants' argument that, because "the developing market could easily absorb double the rate of output (presently about 30 Ph.D.'s/year in Ontario) during the next five years" and because of the serious undersupply of qualified candidates, assigned quotas for the Ontario system would be meaningless.

We agree that adequate capacity and quality exists within the department and that decisions about specific research areas should be made within the individual universities. We accept the criticism that excessive effort has been devoted to "traditional and classical areas of research" and that our efforts should continue to be re-directed towards research more pertinent to the practice of Mechanical and Aeronautical Engineering. We

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agree that the relevance of the research work would be enhanced if support were made more dependent on contracts from high technology industry and appropriate federal government departments.

We intend to pursue our proposed five-year plan and strengthen our contacts with industrial and government laboratories. We will explore the possibility of establishing an industrial research institute (or an office of industrial research) since these institutes are noted as having a highly beneficial effect on the research of the faculty and graduate students.

We applaud the recommendation that a good Ph.D. programme should provide breadth by means of well balanced course work and depth by means of a thesis involving substantial research on a specific and topical engineering problem. Doctoral graduates from such a balanced educational programme will be able to move into industry and tackle problem solving on a broad front.

Conclusion

We hope that it will be clear from the foregoing that we find the reports generally quite acceptable and can endorse all their major conclusions and recommendations. We regard the specific points on which we disagree with the consultants to be minor in comparison to the aggregate of the issues on which we agree.

G. R. Love
November 12, 1973

RESPONSE OF McMASTER UNIVERSITY

TO

REPORT ON DOCTORAL PROGRAMS IN MECHANICAL ENGINEERING

AT ONTARIO UNIVERSITIES

General Comments

We note that this report has addressed itself directly to two most important matters: that of supply and demand of Ph.D.'s in Mechanical Engineering, and that of the basis and direction of Ph.D. work in Mechanical Engineering which should pertain. However, the lack of specific and critical detail in the review of current programs is disappointing. While the report found the "five-year programs generally acceptable", that is, the five-year plans for each institution, the lack of the analysis on which such a review is built means there is no new overall guidance for the planning of the future of our program as part of the Ontario system. It is true that the report deals with many of the facets of Ph.D. Mechanical Engineering studies in Ontario, and numerous specific judgments are made. However, from the information supplied to the consultants in university submissions and undoubtedly gained through their visits, much more analysis would have been expected. It might well have then illumined and reinforced those judgments.

Specific Comments

Certain inconsistencies arise in this report which we wish to note, since they illustrate our main criticism of its failure to provide detailed evaluative judgments of each program in its varying dimensions. The consultants do provide specific comments on the University of Ottawa and on the Institute for Aerospace Studies at the University of Toronto. Such specific comments might well have been expanded, perhaps in even greater depth, to each institution in a manner that would have been equally helpful to those schools in planning their future development.

The consultants claim each program to be acceptable and viable (Recommendation 2), yet they note (A-15) that each department had shortcomings, programs lacked imagination, and needed redirection. Again (A-13) some research is noted as being in a "more important and contemporary area" - with the direct implication that a good deal is not. We would claim that a more thorough visible analysis of strengths and weaknesses, and of less important and more important research, would have greatly strengthened their general judgments and given much guidance to each university. This same problem arises with their judgments on theses, where (A-10) the claim is made that "most theses were indeed reports on creditable doctoral work". Unless "most" means very close to 100%, there is well room for concern which seems to call for detailed exposing. The occasional "inadequate thesis" (A-10) is contradicted by (A-12) "most often the result is a thesis or a paper with little permanent value and no engineering significance". If the latter is true, then the need for the specific evidence and thorough analysis is great indeed.

The consultants stress the need for breadth, both in philosophic terms and specific terms relative to number of courses for doctoral students. (We endorse heartily the concept of a broad program and endeavor consciously to meet it in practice.) Nonetheless, the consultants specifically reject the concept of minimum viable size for a group involved in Ph.D. work in Mechanical Engineering. It appears to us that some minimum size is required to provide the breadth that they advocate for the core program area suggested (A-12and -13). Approximate determination and statement of this from the documentation available to them would seem to have been demanded for reinforcing of such an important opinion.

The consultants, wisely in our view, support strongly the need of cross-linkages between departments and among disciplines. We hold the view that the ease of establishing such cross-linkages is not related solely to size, as implied by the consultants, but rather to many other factors including the existence of high quality graduate work. The latter may well be as much the cause of effective cross-linkages as the result of such, as claimed by the consultants. The report mentions Ottawa, Queen's, Western and Windsor as having working relationships with Civil Engineering. It could well have been noted that in graduate work and research, working relationships at McMaster exist with Chemical Engineering, with Electrical Engineering, and also in terms of an active solid mechanics group between Civil and Mechanical. In terms of fruitful external contacts, small departments are again emphasized - but McMaster (not specified as small, but we are probably in that category) has also had the same "outward-looking viewpoint" in conjunction with work at NRC, at other universities, and very closely with local industry. Here again, presentation of definitive detail and some asserting of the precise indicators being used would have yielded a clearer picture. We do not consider that clear evidence has been presented to favor one size of department over another relative to the establishment of productive external relationships.

The question of assignment of specific research areas to particular departments is again one in which the report leaves us somewhat unclear. Recommendation 3 clearly asserts that such assignment should be made within the university, and not by an outside agency. We agree definitely with this as a general and sound philosophy. At the same time, we accept just as definitely the idea that voluntary associations such as CODE and COU will aid in achieving a "reasonable degree of rationalization" (A-17). This might seem to be at variance with Recommendation 3, but to us is the correct interpretation of the strength of a consultative arrangement in the Provincial system of engineering education. Equally at variance is the warning on Page A-13 that certain closely related efforts (in metal cutting, etc.) do not overlap but could easily do so in the future. This appears to us to be precisely the reason for having careful specific advice from those who have an overview of the whole system, and the reason for close institutional coordination. We consider therefore that the availability of high-level knowledgeable advice, of periodic consultation, and of avenues for coordinated voluntary efforts are all ones that should aid in having the university itself decide on the most productive and useful assignment of specific research areas. The consultants were, as we understand it, to give such direct guidance and advice in this area as in others (for example, Page A-27 in their opening statement), and we are sorry to note that so little of it has been provided.

We now turn to one important area where we cannot accept the consultants' view as being at all consistent with actuality - certainly at this University. The consultants list (A-14) eight areas, with numerous topics in each, in which they claim "little or no research effort is to be found". Research at McMaster has gone on and is going on in six of these categories, and the majority of our graduate theses can be listed in such groupings. In addition, most of the remaining research topics that have resulted in theses at this University can be identified as having strong current relevance to industrial problems. Also surprising, in this admittedly partial list, is the very small number of topics related to design and production engineering which they have lauded (A-15) and to which they have requested increased attention.

The consultants have emphasized a number of excellent notations and concepts with which it is easy to agree most enthusiastically. We do so, of course, in regard to their statements on design and on production engineering (A-15), on which we have expended much of our effort for a number of years. They also draw definite attention to the "steeple of excellence" concept, using the Institute of Aerospace Studies as a fitting example. No follow-through of these concepts, however, is given in terms of noting which fields, groups, and departments have established at least a strong base for such a steeple, and hence which should be encouraged and supported. Acclaiming of a carefully selected number of such areas, based on adequate quality indicators, would again have provided an aid to planning and, indeed, an aid to future financing. We regret that this opportunity was lost.

Response to Recommendations

Recommendation l. We agree with the recommendation that there should be no assigned quotas for Ph.D.'s in mechanical engineering for the Ontario system as a whole nor for the individual institutions. We concur with the consultants' view of the shortcomings of the CEMC report on doctorates in engineering, and in their view of the projected needs even though no documentation is provided for the latter. The opinion that the controlling factor is now and should continue to be the supply of entering candidates is again one that we do not dispute. While the consultants judge that our system could accept up to 300 doctoral students as compared to a projected total of 170-180 by 1978, they are of the opinion the number may well drop to 90. The logical expression of this summary opinion should have two aspects, in our view, and both are missing. Firstly, there is complete omission of any qualitative judgement about the wisdom, reality or capability of each department relative to its five-year projections on enrolment. Secondly, there is no indication of how a reduction, for example to 90 in the system, should be met. We regret these omissions, as we do that of the opinions that might have been expressed regarding matters such as desirable "cross-flow" of Canadian students (i.e. doctoral studies in a different institution than undergraduate studies).

Recommendation 2. The consultants note that the quality of each of the existing programs in the total system is acceptable, and in their view viable. The consultants bring knowledge and a deserved high reputation to such a judgment - and we can but accept it as valid. Again we express regret that the comparative analyses and criteria selected were not detailed. Assistance in remedying weaknesses, building on strengths, and planning for changes would have been rendered in a most helpful way if such evaluative material had been derived and presented.

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Recommendation 3. We have indicated earlier in our response that we agree with universities retaining the power of decision in assigning specific research areas (rather than outside agencies). We have indicated also that adequate decisions require as wide and objective information and evaluation as can be obtained. In this report we are left with little that can speak directly to our condition and to provide us with guidance.

Recommendation 4. As indicated previously, we support the principle of this recommendation, and feel that in practice we meet the spirit of it, though our students average between 5 and 6 full courses, with a minimum of $4\frac{1}{2}$ courses.

Recommendation 5. This applies to the University of Ottawa, and we note only that we support fully the concept of special roles, including organizational framework, for individual universities.

Recommendation 6. It is possible for us to endorse this recommendation, provided it can be used in context. The correct context overall is at least the whole Faculty, if not the whole University, and the greater degrees of freedom associated with a larger "pool" makes it easier to continue to adhere to high quality, competence and potential as criteria for faculty appointment. This particular recommendation is the only one, surprisingly, based on a presentation of a detailed analysis of data provided the consultants; and we find their analysis a useful summary of the problems that can arise through non-uniform expansion.

Recommendation 7. We consider this area to be one outside the terms of reference of the consultants. We also point out that the "Ring of Iron" was more specific three years ago when they proposed a greater de-coupling of research from graduate work. This latter element is not dealt with at all by the consultants. It is to be noted that the financing of universities is being studied in Ontario by COU jointly with the Committee on University Affairs. The consultants also have full rights to be concerned about and indeed give suggestions as to financial needs in the area of Ph.D. work including research. Their recommendation to stimulate the entrance of qualified students to doctoral programs through selective use of scholarships (A-23) gains our support, as would other means of support of research activities. However their concept of separation of research from teaching is one we do dispute strongly. To us, the research activity associated with doctoral work is an inherent inseparable part of the total teaching-training process. Their final recommendation as part of recommendation 7 is therefore one that is unacceptable, and at the very least is a major, and wrong, over-simplification of a complex problem.

General. We concur with other specific recommendations not included in the consultants' summary list. We agree that foreign students should be supported more strictly on the basis of aid to developing nations; we agree that part-time study at the doctoral level is not likely to be fruitful, at least in our situation; we agree that doctoral work in design and production should be encouraged; we agree that research institutes are a useful adjunct to faculty research; and we agree that faculty mobility should be encouraged, particularly with industry.

12 December, 1973

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CABINET DU RECTEUR

OFFICE OF THE RECTOR

November 27, 1973

Dr. M.A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Ontario Council on Graduate Studies,
Council of Ontario Universities,
102 Bloor Street West,
TORONTO, Ontario. M5S 1M8.

Dear Dr. Preston,

This is a reply to your request for the University's comments on the ACAP consultants' report on Mechanical Engineering.

As you know, doctoral study in Mechanical Engineering is of recent origin in Ontario. The Department of Mechanical Engineering at the University of Ottawa is no exception. It initiated Ph.D. studies in 1967 with five students. Two of these have obtained their doctorate and three are completing their program. Admission to the program was discontinued in 1969. During the past four years we have recruited new staff with established reputations as investigators. We are therefore pleased that the consultants have recognized that the resources and research caliber of the Department are more than adequate for a high quality Ph.D. program and have recommended that the program be reactivated.

We value the consultants' recommendation that: "Ph.D. graduate work in mechanical engineering at the University of Ottawa should be integrated into a multidiscipline effort in conjunction with the other engineering departments of the faculty to provide the vehicle for a nondesignated graduate degree in engineering" (page A-25). We have, in fact, been considering implementation of this concept for the past year and in this connection draw your attention to the comments we made in our recent brief to C.U.A. (page 23): "Plans for the development of a common Ph.D. program in Engineering as opposed to the specialized programs given by the individual engineering departments have been held up by the ACAP engineering assessments. After their completion we shall reopen the possibility of this development in the light of the ACAP reports". We believe it to be a direction towards which we may progress in the near future.

Our immediate goal is the reactivation of our doctoral program; the long range integration of Ph.D. work in Mechanical Engineering into a multidisciplinary system may then follow.

Since we consider it our duty to provide higher education in a bilingual environment, we were pleased to read in the report (page A-18) that: "The University of Ottawa is unique. It has the mandate to provide an educational opportunity for the French-speaking population of Ontario, which numbers some 500,000 people. This is the only bilingual engineering school in Ontario. There is a steady demand and limited supply of bilingual personnel with a high competence in modern engineering technology. We believe Ottawa can develop as the centre to provide such an educational experience and would recommend full encouragement in this direction." (page A-18)

Yours sincerely,

Roger Guindon

Roger Guindon, O.M.I.,
Rector.

copy: Dr. Paul Hagen
Dr. Antoine D'Iorio

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QUEEN'S UNIVERSITY
KINGSTON, ONTARIO
SCHOOL OF GRADUATE STUDIES AND RESEARCH

December 7, 1973

Dr. M. A. Preston
Executive Vice-Chairman
Advisory Committee on Academic Planning
Council of Ontario Universities
102 Bloor Street West
Toronto, Ontario M5S 1M8

Dear Dr. Preston:

I apologize for not sending forward anything in connection with the planning assessment on mechanical engineering. The Head of the Mechanical Engineering Department told me that for the moment Queen's should be content to have its response as general support to the comments of the discipline group. I neglected to report this and do so now.

I expect, however, that a University response or comment will be prepared on the ACAP report--probably at the time the group of reports for the engineering disciplines have been examined.

Yours sincerely,

R. McIntosh
Dean

RM/mb

UNIVERSITY OF TORONTO
School of Graduate Studies

OFFICE OF THE DEAN
Toronto 181, Canada

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November 7, 1973.

Dr. M. A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Council of Ontario Universities,
102 Bloor Street, West, 3rd Floor,
Toronto, Ontario,
M5S 1M8.

Dear Dr. Preston,

The University of Toronto welcomes the philosophical approach to planning found in the report to ACAP by the Mechanical Engineering Consultants, but regrets that the report does not provide evaluations of the individual programs within the Ontario system. The observations they have made covering the whole province about the quality of students, the level of training and the employment prospects for graduate students are useful with regard to the discipline as a whole, but the lack of specific data and of evaluations of Departments and programs lessens the value of the report.

We support their comments on admissions and future enrolment in Mechanical Engineering. It is evident from this study that, contrary to the CEMC Report, there is no problem of a gross oversupply of Ph.D.s in the discipline; in fact, there would seem to be a danger of undersupply.

Unfortunately the report contains no tables on enrolment which would allow us to comment on the question of critical size. Without such data and given the absence also of qualitative evaluations of the Departments, it is difficult to discuss adequately the claims they make about minimum size. We would also have appreciated tables on degree requirements, faculty research grants, output of Ph.D.s and other data on which the consultants must have based their views.

We recognize the imbalance between the numbers of Canadian and of foreign students but see no immediate steps that can be taken to correct the imbalance, beyond encouraging more Canadian undergraduates to pursue their graduate studies in this country.

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The following comments are in response to the recommendations of the consultants (numbered as on pp. A. 24 - 25):

1. We support this recommendation.

2. While we welcome this general evaluation of the programs, we would have welcomed even more a quality assessment of individual programs. We regret that we do not have more of the information and the reasoning on which they base these overall statements, particularly in light of the comments made on pp. A 12 and 13 concerning the lack of engineering relevance in many Ph.D. theses. We would ask for an expansion of these comments from the consultants with reference particularly to the quantitative and qualitative nature of their Departmental evaluations.

3. We support this recommendation, though again drawing attention to the need for clarification of the remarks made on pp. A 12 - 13.

4. We consider this requirement inadequate. We believe that there should be two academic years of course work (8 courses) beyond the baccalaureate, that is one academic year of course work (4 courses) beyond the master's degree.

5. We wish to comment on the statement that, if the multi-departmental Ottawa program goes ahead, "no new mechanical engineering departments or enlargements of the present be required in the next five years". We believe that the comment on enlargement should not apply to individual departments. Should some programs be curtailed by the universities, other departments should be free to expand into the areas left open.

7. We find it difficult to follow the logic of this recommendation in the light of statements made on pp. A 22 - 23. The consultants claim the present BIU weighting probably reflects the cost of Ph.D. programs in engineering. Given that they also see the possibility of a shortfall in the future supply of Ph.D.s in Mechanical Engineering, we do not see how reducing the BIU weighting would encourage departments to increase their enrolment numbers. We are concerned also at what appears to be a recommendation for excessive dependence on industrial research funds, since fluctuations in this area could have harmful effects on the stability of some programs. The question of the separation of funds for teaching and research (p. 23) has been discussed at length in Ontario over the past two years. Without more information on how the consultants arrived at their position on research funding, and what exactly they mean by it, we cannot accept this recommendation.

This set of recommendations seems to us to be either inadequately considered or inadequately presented.

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A point concerning the UTIAS research activity should be made. Shortly before the consultant's assessment there were two UTIAS faculty members whose work was related to metallurgy and materials science. Both maintained close relations with the Department of Metallurgy and Materials Science, in spite of the geographical separation, and with the Materials Research Centre. Because of retirement there is at present only one staff member in this area who maintains contact with the materials research group.

Again we must express our disagreement with ACAP's practice of not giving to each set of consultants copies of earlier ACAP assessment reports. We believe many of the pitfalls encountered by consultants as well as the shortcomings of their reports could be avoided if they had a clearer notion of the work of previous groups.

Yours sincerely,

a E Safarian

:erb

A. E. Safarian,
Dean.

cc - Dr. Evans
Mr. Sword
Prof. Forster

Response of the University of Waterloo to the Report of the Mechanical Engineering Consultants to the Advisory Committee on Academic Planning

submitted to ACAP, November 21st, 1973.

The University of Waterloo wishes to express its general disappointment with the report of the Mechanical Engineering consultants. This report falls far short of providing the necessary critical review of the graduate programmes in mechanical engineering in the province that is necessary if the universities are to effectively plan the future development of their doctoral programmes. The report contains a number of inconsistencies which we will comment on below and also makes a number of general statements which must be challenged. There is only one specific statement in the report about the programme at the University of Waterloo and this requires only a brief comment. Finally, we state our position on the several recommendations which the consultants make.

General Comments:

Our major complaint with this report is with its failure to be more critical. The consultants are reluctant to criticize any aspect of any of the programmes in the province with the exception of the University of Ottawa. They state that they find all of the programmes to be of acceptable quality and of viable size, and yet in other parts of the report they indicate that they do not consider that all is well. They point to a lack of imagination in the development of some of the programmes. They also say that while every programme has strength in some area, there are also some weaknesses in all programmes. The report would have been far more helpful to the universities if the consultants had been willing to identify these strengths and weaknesses and had given some justification for their general conclusion that all of the programmes are acceptable.

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One of the major inconsistencies in the report centers around the attempt by the consultants to justify the existence of small groups in certain programmes. They clearly do not accept the concept of critical size for a group to be academically viable. At the same time, they point out, in our view correctly, the need for breadth in the doctoral training of mechanical engineers in the 1970's. The consultants, in fact, go further and recommend that all programmes have a minimum course requirement covering a broad spectrum of the fields of mechanical engineering. They do not address themselves, however, to the question of how a small department will be able to provide the kind of breadth which they feel is essential and the kind of course coverage which they recommend should be part of every doctoral programme.

As well as being generally inconsistent on this subject, the consultants in their defence of small programmes make certain statements which must be challenged. They state on Page 16 that, "A drawback to a large group is the difficulty of adapting to change". They go on to mention the cross linkages which have been developed by small departments at Ottawa, Queen's, Western and Windsor with other engineering departments, notably civil engineering, and with outside agencies. The consultants make no mention of the fact that at Waterloo, which has a large department, there are also linkages with other engineering departments. In fact, there exists a graduate division consisting of members of the Mechanical and Civil Engineering Departments which fosters research and graduate activity in the general area of solid mechanics. There is also cooperation in the field of materials between the group in mechanical engineering and other groups in chemical and civil engineering. Waterloo also has developed effective linkages with outside agencies and in particular with industry. It is quite clear that the size of a department is not a bar to the establishment of these relationships as the consultants imply.

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We also submit that size is not a bar to flexibility. Indeed, the department at Waterloo has adapted its programme to the modern developments in mechanical engineering to a very high degree. To support this contention, we can refer to the consultants' list of, what they call, underexplored mechanical engineering problems on Page 14 of their report. The consultants state at the middle of Page 13 that there is little or no research effort in the Ontario educational system in these areas. This statement is simply not true of the programme at this University.

The Mechanical Engineering Department at the University of Waterloo has active graduate and research programmes in many of the fields which the consultants list: In the field of Power Transmission there is work dealing with problems in gearing; there is work in system analysis and emissions which fall under the general heading of transportation; in the field of energy conversion there is work in the area of gas turbine flow, solar energy devices and cryogenics; in fluid systems there is activity in piping system design, and in hydraulic power transmission; in the area of multi-phase flow, there are active programmes in aerosol dispersion, flow of dust and sediments and blood flow; in solid systems, there is work in systems structures, creep, fatigue and fracture of engineering structures, in the design performance of composite materials and structures, and in pressure vessel design and the critical problems of access openings; under the heading of production problems, there is work at this University on drying processes, casting processes, materials handling equipment, combustion control, ignition, growth and extinguishing of fires and environmental systems design and control.

The contention of the consultants that a large department will be too inflexible to move quickly and effectively into the forefront areas of the field is simply not supported by the facts.

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In their analysis of the supply and demand for Ph.D.'s in mechanical engineering, the consultants present a view that we find ourselves in general agreement with. We agree that there is little danger of an overproduction of mechanical engineering Ph.D.'s given the present level of doctoral enrolment in the province. We also agree that if the supply of qualified students drops by 40% from its present level as the consultants suggest is likely to happen that the production of Ph.D.'s may fall short of the demand. But even in this section, the consultants fail to make any comment on the universities' planned enrolments and, in particular, on their consistency with the likely supply of qualified students. If the enrolment in the province does drop to 90, as they suggest is likely, will there really be enough students to maintain all of the existing programmes at a viable level? The consultants clearly seem to think so but they provide no evidence or arguments to support their position.

We would like to comment on one other general statement in the report. On Page 19 in the section devoted to the University of Toronto Institute for Aerospace Studies, the consultants express the view that they "do not visualize similar centres arising elsewhere". We share the consultants' high opinion for the quality of the work carried on at this institute and we agree that it is a "high steeple, not just in Ontario but in the entire Canadian scene". We submit, however, that other centres of excellence could arise on the Canadian scene if research funding were made available at the same level as has been available to UTIAS. We also submit that Canada and Ontario would benefit from the development of other such centres of excellence.

Specific Comments:

The only comment in the report which refers specifically to the programme at the University of Waterloo is contained in Section D of Chapter VI on Metallurgy/Materials Sciences. The

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consultants have recognized the role which this group plays within the Mechanical Engineering Department and have expressed their approval of the arrangement. The University agrees with their comments.

Comments on Recommendations:

Recommendation 1 - we agree with the recommendation that there should be no assigned quotas for Ph.D.'s in mechanical engineering either for the Ontario system as a whole or for the individual universities. We regret, however, that the consultants have not provided the universities with advice as to whether or not their planned enrolments are realistic.

Recommendation 2 - while we do not challenge the statement in this recommendation that the quality of each of the existing programmes in the total system is acceptable, it is at the same time not a very helpful statement in terms of planning. The Ph.D. programmes at each university may be acceptable and viable at the present time but would these programmes remain acceptable and viable if they were to expand into other areas or to contract their activities to cover a smaller range of specialties. One could read this recommendation as a *carte blanche* for any of the departments to go into any area in mechanical engineering. We doubt that this would be in the best interests of rational planning of doctoral work in this field.

Recommendation 3 - we agree that decisions to assign specific research areas to particular departments should be made within the university and not by an outside agency but this does not mean that the universities should not have the best advice available in order to assist them in making these decisions. Indeed, it was our understanding that one of the consultants' tasks in this assessment was to provide just this kind of advice to the universities. They have failed to do so and, therefore, the report is of little value in this respect.

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Recommendation 4 - we agree in principle with this recommendation. At the present time, the University of Waterloo does not have any formal course requirements for the Ph.D. in engineering. This matter is currently under review in the Faculty of Engineering. Nevertheless, the vast majority of doctoral students take some courses as part of their programme. This is in addition to the broad course background which the students obtain in their Master's work. Since the University of Waterloo requires the Master's degree for admission to doctoral work in engineering, much of the necessary course work background has already been obtained by the students before they enter their Ph.D. programme.

Recommendation 5 - we make no comment on this recommendation.

Recommendation 6 - we give qualified support to this recommendation. While we recognize the need for the universities to correct the unbalanced age distribution insofar as this is possible, this should, nevertheless, never be the overriding consideration in hiring new faculty. The University of Waterloo will continue to hire the best qualified people for any positions which are vacant. We expect that in the normal course of time, with retirements, people leaving and new hiring, that the age distribution will gradually become less unbalanced.

Recommendation 7 - it is probably unnecessary for the university to comment on this recommendation since it is really beyond the terms of reference of the consultants. This question is under active consideration already in the university system. The solution is not as simple, however, as the consultants imply in the statement following this recommendation.

Response of the University of Western Ontario to the Report of the Consultants on Doctoral Programs in Mechanical Engineering of the Advisory Committee on Academic Planning.

November 20, 1973

This report was prepared by a Committee of Senate charged with generating a response to the ACAP Consultants' report on doctoral studies in Mechanical Engineering.

This report is perhaps as remarkable for what it does not say as for what it says. A careful review leads to the conclusion that many of the problems involved in the mounting and maintenance of Ph.D. programs have been considered. Some of these points are worthy of comment.

(1) The consultant's conclude that "a doctoral program in every department is essential" (A-2) and that "group size has little effect and ----- successful programs can exist in small as well as large departments" (A-2). This position emphasises the view that an advanced graduate program has important consequences in the production of "a dynamic undergraduate curriculum" and a vigorous and active faculty. In effect it is the judgement of the consultants that these benefits outweigh the disadvantages which sometimes accompany small programs.

(2) In relation to the above statement the consultants enunciate a plan for a Ph.D. program which entails a limited number of rather general graduate courses (1½ years, A-10) comprising mechanics (including kinematics and vibrations) solid mechanics (including elasticity and plasticity) fluid mechanics (including acoustics) and transport phenomenon (including conduction, convection, diffusion and radiation) (A-12) and eschews "highly specialised graduate courses" (A-10). Building on this broad base they suggest "a good Ph.D. study in " mission-oriented research" is a fundamental study of basic processes and principles --- with an application of the results to real industrial engineering problems" (A-13). This model is one which the local mechanical engineers completely support and seek to implement.

(3) We note with concern the preponderance of non-Canadians engaged in mechanical engineering studies (A- 6). The suggestion that such students should be supported by CIDA is not new nor is it likely that CIDA would support students in the numbers presently involved. The projected shortages of mechanical engineering candidates that may result from altered immigration regulations might well be off-set by a scholarship program (A-23) aimed at Canadian students. We have commented in other ACAP responses on this possibility of increasing Canadian participation in graduate studies.

(4) The consultants make a plea that "the voice of industry should be heard more often in discussions of the training of engineers at the graduate level " (A-23). The regular use in the engineering school at Western of Industrial Consultants (e.g. from A.E.C.L., N.R.C. and industry) in all programs has strengthened these programs and has increased the employability of the products. This activity has been faciliated by the establishment of an Advisory Council rooted in the major engineering industries of the country.

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(5) Finally we would like to comment on the word "unique" in recommendation 5 (A-25). This University, since the initiation of its program, has produced 20 Ph.D. graduates (six per year for the last three years) in Engineering Science not designated as "Mechanical" or as any of the other traditional specialties. We have evidence that such products are readily employable and useful members of the profession not restricted in outlook by rigid stereotypes and capable of attacking interdisciplinary problems. Accordingly, we encourage Ottawa to follow in our footsteps but we would not accept the notion that recommendation 5 is in any way a unique proposal.

A Response of the University of Western Ontario to the Advisory Committee on Academic Planning with respect to the Engineering Specialty Assessments (1973).

November 29, 1973

Historical Aspects

Approximately 20 years ago (1954) on the recommendation of the Faculty of Arts and Science the Senate of the University of Western Ontario established a Department of Engineering Science. This Department undertook to gather the faculty necessary to establish an independent Faculty of Engineering Science and Faculty status was granted to this group in 1960. The beginning of formal graduate study was the offering of an M.E.Sc. program which received the approval of the Faculty of Graduate Studies and Senate in 1961. The first candidates (4) were admitted in September 1962 and by 1964-65 the number of M.E.Sc. candidates had risen to 18. In October 1964 the Faculty of Graduate Studies approved the establishment of a Ph.D. program in Engineering Science and the Senate supported this action on January 29, 1965. From the outset an effort was made to emphasise the interdisciplinary nature of the program and graduate training was offered in a limited number of areas which at that time included chemical and biochemical engineering, soil mechanics, structural engineering and thermodynamics. Since its inception the Ph.D. program has produced a number of graduates

1969 - 1
1970 - 1
1971 - 6
1972 - 6
1973 - 6

In 1973-74 there were enrolled in the Ph.D. program 29 full-time students and 15 part-time students. All of these students have received or are enrolled in programs leading to a Ph.D. in Engineering Science and none of them has received a degree designated as serving one of the traditional specialties of engineering (e.g. chemical, mechanical, etc.).

The "Ring of Iron" published in 1970, among other things, recommended that the Faculty of Engineering Science drop the "Science" from its name (Ring of Iron, p. 77). The Faculty, after considering this matter, elected to retain this name as it did its interdisciplinary programs. The "Ring of Iron" did recognise the interdisciplinary nature of the programs by recommending that Western "concentrate" on environmental engineering which was acknowledged at that time to be a foretaste of the future. At that assessment it was also noted that "Western has gained distinction with its work in industrial aerodynamics, electrostatics and bioengineering". (Ring of Iron, p. 76).

Present Assessment

As a consequence of dissatisfaction with the stringency of Ph.D. recommendations in the "Ring of Iron" as adopted by the Council of Ontario Universities, the Council of Deans of Engineering has sought a reassessment of the Ph.D. programs in Ontario Engineering Schools. This task was undertaken under the aegis of the Advisory Committee on Academic Planning and something which has been erroneously termed a "mini-appraisal" has been performed.

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The conditions under which this appraisal was undertaken are of particular interest because the form which this assessment has taken fails to take cognizance of work of an interdisciplinary nature which may be deemed to be outside the traditional specialties of civil, electrical, mechanical, chemical and metallurgical and materials sicence engineering. Examination of the five reports which have been received reveals rather remarkable differences between reports in spite of the fact that the consultants seem to have been given substantially equivalent instructions (with the possible exceptions of mechanical and chemical groups who do not specifically report their terms of reference). Remarkable perhaps are the prevalent comments about "critical size" when the printed terms of reference contain no mention of critical size.

As the present assessment has been conducted, it seeks to determine whether the engineering schools of the province contain five individually certifiable traditional specialties of engineering. If this was the objective of the assessment it was not so stated in advance. Not surprisingly, the large schools with substantial groups in each of the specialties survive assessments of this sort. The smaller schools regardless of the quality of their operations when judged in this particular frame of reference are found wanting in one or more of the traditional specialties. That is not to say that the discipline is not represented in the school since it must be to meet undergraduate instructional needs but the group practising the specialty is small and does not meet some arbitrarily defined critical size.

What can a school that is faced with this difficulty do? Aside from the obvious and in general unacceptable possibility of retiring from competition the researcher in the small "sub-critical" groups seeks to meet the need for interaction with other professionals and to develop his own intellectual pursuits by developing liasons with other individuals in related fields. The consequence is that individuals with different backgrounds, information and skills address themselves to problems which they have in common. At its best this kind of development can be the most exciting research conceivable. At its worst the products of the activity may be minimal or zero. However, we would contend that operations of this sort which stem from small interdisciplinary groups are potentially of great importance and furthermore, that the present assessments carried out along stereotyped lines may not detect these activities and are likely not suited to the evaluation of them.

It will be evident that interactions with individuals in other disciplinary specialties, however integral to the research in hand, will not permit the specialist group sparsely represented on staff to meet the criterion of critical size when the assessment is carried out in the framework of traditional disciplines.

The situations which prevail at Western in which these difficulties of assessment are most easily identifiable lie with the Electrical and Materials Science groups although the prevailing interdisciplinary attitude of faculty members in other groups leads to a reduction in the vertical integrity of the traditional specialties and to an enhancement of horizontal interactions between specialties. Encouragement of this horizontal interaction has been a conscious policy within the Faculty of Engineering Science and is a major determining factor in the decision of the Faculty to offer an Engineering Science program rather than programs in the traditional specialties.

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The Engineering Science Concept

The absence of departmental structure and all that it contributes to specialty tribalism, the limited dimensions of the Faculty (approximately 43 F.T.E.), and the existence of congenial relations has led to development of extensive interaction and collaboration between groups within the Faculty. For similar reasons it has also been possible to develop interfaculty research activities in the biomedical area, (collaborative activities in both biomedical engineering and applied physiology), in radioscience (as participating members in the Centre for Radioscience) and in computer science (where the systems engineering group has developed a collaboration). The abiding interest of the Faculty in environmental matters has promoted interaction with other parts of the University which may be expected to bear fruit in the future. It should be noted that in all five of the assessment reports the comments on the quality of the work in hand were favorable.

In effect, circumstances have dictated that a particular course of development be followed. It would be our contention that this course has led to much that is valuable and worthy of development. While the route we pursue may be inappropriate to other Engineering Schools we would request that we be judged in this framework and not in the traditional format which cuts across rather than displays our most effective activities.

These remarks may be concluded by a statement that as recently as November 14, 1973 and with the full knowledge of the various consultants reports, the Faculty of Engineering Science reaffirmed its intent to continue to offer undergraduate, masters and doctoral training in Engineering Science and not in any of the specific sub-disciplines.

UNIVERSITY OF WINDSOR

RESPONSE TO THE ACAP CONSULTANTS

"Report on Doctoral Programs in Mechanical Engineering in Ontario Universities

The final report was received on Oct. 25, '73. The ideas expressed and the recommendations made in the report are the result of a thorough, in-depth study of the Ontario system in Mechanical Engineering. The recommendations made will assist individual departments to further strengthen certain areas and to alter the direction of some research activity to better reflect the future needs of both the Province and Canada as a whole. We wish to compliment the team of consultants for doing such a capable job in spite of rather severe limitations on time.

There were two specific references to the M.E. Dept. at the University of Windsor, both of which were favourable. The first of these followed the statement, "The cross linkage between departments within small faculties was noticeably more distinct tending to create an educational milieu that fostered high order graduate work." At Windsor we have always encouraged this cross linkage and our recent reorganization into the divisional structure for graduate studies will increase the cross linkage still further.

The other reference to Windsor was, "their relationship with the Industrial Research Institute brought them into contact with the high technology problems of industry". The obvious advantages of this contact are clear. However during the visit by the consultants it was even more apparent that the presence of IRI on campus and the industrial problems which came to the Department as a result, were looked on as a great advantage. We would suggest that the I.R.I. has had such a positive effect in our graduate program that the presence of I.R.I. should be considered whenever the graduate program is under discussion.

We shall now comment on four specific recommendations which were made.

1. "There should be no assigned quotas for Ph.D.'s in Mechanical Engineering for the Ontario system or for individual departments".

   Comment: This is a logical recommendation in view of the present situation. We cannot find a sufficient number of qualified students at present to satisfy even a minimum requirement. All evidence points to a severe shortage of engineers in the very near future and this will apply to all levels of study.

2. "The Ph.D. program at each university was found to be acceptable and viable," and "assignment of specific research areas to a department should be made within the university and not by an outside agency."

   Comment: These two recommendations have been grouped together for comment since they are closely related. We suggest that the departments were found to be strong and viable because they have been allowed to develop in a way that takes advantage of their strengths and reflects the needs of the country related to these strengths. For example, a few years ago, the Department in cooperation with I.R.I. identified "noise and vibration" as a field of study which would require increased attention in the future. This attention would be directed at all levels of student training plus the development of a facility to do research and consulting for industry. The Department subsequently built up strength in this field supplemented through the appointment of an adjunct professor. The result of this rapid response to a need is the growing number of projects and requests coming to the I.R.I. from Canada and the U.S.

3. "The normal mechanical engineering Ph.D program should contain 1 ½ years of a broad selection of courses beyond the Baccalaureate".

Comment: This recommendation is certainly acceptable and exactly in line with the direction of our plans for our Faculty. About 1 1/2 years ago we created a divisional structure at the graduate level for the Faculty. The three divisions which were created would look after course offerings and programs for all graduate students. Core courses were identified in each division and these courses had their origin in a variety of the departments within the Faculty. It appears that the steps which we have taken will result in changes directly in line with this recommendation.

RESPONSE BY McMASTER UNIVERSITY
TO THE ADDENDUM TO THE
CONSULTANTS' REPORT TO A.C.A.P.
ON MECHANICAL ENGINEERING

We are pleased to note the emphasis on increased graduate work and research in engineering design, and on a project or systems approach to larger and integrated research efforts calling for concentration of departmental resources. We assert that both elements of this philosophy have been paramount ones in the development of graduate work in mechanical engineering at McMaster over the last decade, and we will continue to stress such an orientation.

We are equally pleased to note the strong support given to us through a most positive qualitative evaluation of our current research efforts and graduate degree programs in engineering design and in manufacturing (production) engineering. We intend to continue strongly with our efforts for good inter-departmental and inter-Faculty participation in this latter program along with close collaboration with industry and other universities. A minor point of correction to note is that our Advisory Board has wide industrial representation from Ontario and Quebec, not just the Hamilton area.

June 12, 1974

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APPENDIX D

PROCEDURE OF PLANNING STUDY AND TERMS OF REFERENCE

Procedure for Mechanical Engineering Doctoral Planning Assessment
conducted by ACAP in co-operation with CODE
1972-73

A. Tasks Requested from Discipline Group (with help available from ACAP at all stages)

A.1. Meet with representatives of ACAP and CODE and discuss the specialty fields assigned to this assessment. An initial meeting of the five engineering discipline groups may prove desirable. The field allocations may be altered by ACAP as a result of these discussions and CODE comment.

A.2. Suggest a panel of suitable consultants from which ACAP may choose. ACAP will refer the list to CODE for comment before acting.

A.3. Examine and comment on pro formae to be used for the gathering of information on current, past and future programmes as described in paragraph B.1.

A.4. Examine and comment to ACAP on the adequacy of the data collected on current and past strength. CODE will also be asked to comment on the data reliability.

A.5. Both in consultation with ACAP/CODE representatives and separately, consider the situation revealed by the tabulation of proposed future programmes and consider whether future plans should be modified or developed in more detail. As a result of this step, individual universities may wish to revise the material described in B.1.d below.

A.6. Possibly develop a tentative plan for development of established or new doctoral work in Ontario paying attention to adequate coverage of fields and specialties. Any such plans will be reported to ACAP which will transmit them to the consultants and to CODE.

A.7. For this assessment, the discipline group shall consist of a member of each of the Departments of Mechanical Engineering, that member being the chairman unless the chairman delegates this responsibility to a colleague on a permanent basis.

B. Information from Universities

B.1. Each university is asked to supply to ACAP, in the form indicated by ACAP after comment by CODE and by the discipline group (paragraph A.3.).

information as follows:

a) for each specialty field determined in A.1.

   (i) current list of faculty members showing fraction of research and graduate instruction time devoted to the field (for part-time professors show the time spent on university duties);

   (ii) numbers of full-time and part-time faculty members for each of the past five years;

   (iii) for the current year and preceding five years, number of (1) master's and (2) Ph.D. candidates and (3) post-doctoral fellows doing research in the field full and part-time shown separately.

Under these three headings one individual may appear under more than one category.

b) for each "department" which offers doctoral work in the fields of this assessment

   (i) Curricula Vitarum of each faculty member (Assistant Professors and higher) showing inter alia complete publication lists, research funding in the past five years, and graduate students and post-doctoral fellows supervised during his career, and specialization.

   (ii) resources of space - a statement indicating the department's view of the adequacy of its space, and, in connection with the future plans in (d) below, discussing future space provision;

   (iii) number of Bachelors' graduates in mechanical engineering and number of qualifying or make-up students each year for the last five years;

   (iv) other general items relevant to research and graduate study,
      a) major laboratories and equipment, over $5,000
      b) computing facilities;

   (v) support from related departments including shared teaching and research;

   (vi) description of any inter-university arrangements for graduate work.

c) table of characteristics of graduate students in the department in previous five years, separately for Master's and Ph.D., breaking down numbers by:

   (i) Full-time and Part-time;

   (ii) immigration status (3 years) and country of first degree;

   (iii) sources of financial support;

   (iv) time to reach degree;

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(v) drop-out number;

(vi) degrees granted;

(vii) post graduate employment of Ph.D.'s
  a) immediate and
  b) after two years.

d) proposed plans for the future of doctoral work, in as much detail as the department can provide, including the proposed scheme for support of these plans, and accompanied by supporting arguments, including consideration of the sources of doctoral students and an analysis of demand for graudates from the programmes as indicated by previous placement experience. The various headings in a) and b) above should be dealt with quantitatively where possible; as a minimum, planned numbers of faculty and doctoral students should be given. If part-time doctoral work is contemplated, please discuss in detail.

B.2. The material so supplied will be collated by ACAP and transmitted to the discipline group for action indicated in paragraphs A.4., A.5 and A.6.

B.3. Apart from the material described in B.1.d. and to some extent generated at the department level, each interested university will be requested to make an individual statement on its plans for the development of doctoral work in these fields of engineering, in particular the items of future commitment implied by item B.1.d.

C. Terms of Reference of Consultants

C.1. Consider the two special documents related to the coordination of the assessments in Engineering, viz. Engineering Ph.D. Planning and Assessment Procedures, Statement on Ph.D. Studies in Engineering Studies in Ontario, and the material prepared by the discipline group and the universities and obtain other data they may require to carry out the tasks detailed below. They shall be provided with copies of "Ring of Iron", the COU statement thereon, and the CODE, OCGS and APEO responses. They may obtain data and views from any relevant source, such as, for example, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. Consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privileged documents and are not to be made available to ACAP consultants. Consultants shall meet with the discipline group near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

C.2. Report on the adequacy of the present state of doctoral work in "mechanical engineering" in the province in general and in each university where applicable, discussing the following:

a. coverage of fields and specialties, and extent of activity in each

b. faculty quality and quantity

c. nature of programmes offered

d. enrolment size and distribution amongst universities and divisions

e. quality of student body; admission requirements

f. relationship to related disciplines and to the profession

g. physical facilities

h. other matters considered by the consultants to be significant.

C.3. Make recommendations for the development of doctoral work in fields of this assessment in Ontario between 1973 and 1978, taking into consideration such plans as may be developed by the Discipline Group, and, without limiting the generality of the foregoing, dealing with the following points:

a. Desirable doctoral programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider if there should or should not be more activity in fields now producing few graduates in Ontario and also the desirability of developing further application-oriented and inter-disciplinary work and industrial involvement.

b. Desirable provincial enrolments, year by year, in the doctoral study in mechanical engineering and in the major subject divisions where appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue doctoral work in engineering. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply for that market. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and for specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province. Consider techniques for involvement in doctoral supervision of professors in departments which do not take doctoral students in their fields, and the extent to which such activity is desirable.

d. Distribution of enrolment amongst the universities, showing desirable ranges of enrolment.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d.

C.4. It is permissible for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; and appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. In carrying out planning assessments in some disciplines, consultants find there to be an excess or deficiency of programmes in a given area of study, where all of the existing programmes could pass an appraisal, they may, subject to their own judgments of relative

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quality and of other factors (a task outside the terms of reference of the Appraisals Committee), recommend where enrolment should be changed in accordance with the possibilities indicated in section C3 (c).

D. Appointment of Consultants

The consultants shall include one person of wide academic experience in Canada but in a different discipline. The other two consultants shall be engineers of international standing, with suitable administrative and/or teaching experience, and with expertise in some of the fields assigned to the mechanical engineering assessment.

E. Report of Consultants

The consultants submit a joint report to ACAP (tentative date of September 1973). Minority reports are, of course, possible. The reasoning leading to their recommendations should be given fully, in view of the subsequent treatment of the report. The report is submitted for comment to CODE, to the discipline group and to each interested university. There may be informal or interim exchanges of views amongst the discipline group, the universities, CODE and ACAP. Any university which wishes to make a formal statement to COU on the consultants' report shall submit it to ACAP. Any such report shall be transmitted to CODE and to the discipline group. The discipline group shall submit its formal comments and/or recommendations to ACAP and CODE. CODE submits to ACAP its recommendations to COU. ACAP considers the CODE, discipline group and university statements along with the consultants' report and transmits them to COU with its recommendations of the position COU should adopt. Copies of the material transmitted to COU will be supplied to CODE, to OCGS, to the members of the discipline group and to the interested universities. CODE, OCGS and the universities are thus enabled to prepare for direct comment to a COU meeting. The consultants' report may be published together with the comments of CODE, the discipline group and those of any university so requesting, and with the position adopted by COU.

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Amended November 29, 1972.

Engineering Ph.D. Planning and Assessment Procedures

Coordinating Task Force, September 25, 1972

1. The doctoral assessments in Engineering are being conducted as a group. To that end there has been established a Coordinating Task Force to coordinate the conduct of the assessments in accordance with the procedures outlined in this document which is referred to in section C1 of the Terms of Reference for the Consultants.

2. All "departments" of each Engineering Faculty shall prepare a statement presenting their current and proposed Ph.D. activities including:

    (a) areas of research and study
    (b) educational goals and style
    (c) enrolment ranges projected to five years, and other items as defined in section B of the approved "Procedure", including the basic ACAP quantitative data sheets as modified for the engineering assessments.

    The quantitative data sheets, to be submitted to ACAP by November 1, 1972, and the "five-year plans", due by the end of January 1973, will then be distributed by ACAP to the discipline groups for consideration and planning action by the individual institutions and by the discipline groups. Copies will be made available to the members of CODE.

    Departments are encouraged to discuss their preliminary plans with the appropriate discipline group prior to formal submission in January and the discipline groups should be active in their planning function throughout this period.

3. Each Discipline Group will be charged to prepare from the statements a report on Ph.D. activities and plans in their discipline area, noting both apparent conflicts and gaps in both areas of specialization and enrolments. Reports will be distributed as above, by the end of February 1973.

4. Each University may modify the above statements in the light of the above and in consultation with the Discipline Groups and other Universities as appropriate. Subsequently the Discipline Groups will finalize their reports, which are due to ACAP by April 15, 1973.

5. These statements and reports, along with the regular ACAP assessment data (to be prepared during the above process, perhaps with CODE "data bank" collaboration) shall form the data base for the assessment teams. Failure to meet deadlines will not be allowed to delay proceedings.

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5. The Coordinating Task Force will review the detailed terms of reference to be given to the consultant teams, particularly in the educational professional areas. This is scheduled for completion by September 30, 1972.

6. Upon completion of (4) above, the Coordinating Task Force shall recommend to CODE and ACAP whether areas in Engineering not clearly included within the five major discipline areas shall be included within the total of engineering activity without further review, or included within one or more of the major discipline studies, or be subject to a small special assessment process.

7. CODE, with assistance from COU and utilizing outside expertise as needed, shall implement a special study of the engineering manpower situation at the Ph.D. level. This study should be available for consideration by ACAP, the Discipline Groups and the consultants prior to the drafting of final reports and responses. Reports on the progress of this study shall be reviewed by the Coordinating Task Force; the first report shall be due by the end of 1972.

8. The formal assessment and consultative process shall commence on completion of (4) and the consultants shall be provided with a general statement, in addition to the data base material, terms of reference, and other relevant documents. This statement which has been prepared by the Coordinating Task Force and is referred to in section C1 of the Terms of Reference for the consultants is intended to draw attention to some features of the Ph.D. in Engineering which the Task Force considers distinctive enough to merit particular consideration by the consultants. Educational, professional and research concerns will be emphasized. Briefings and discussions with ACAP and the appropriate Discipline Group will complete the first stage of this process. These discussions are expected to occur about one month prior to the first visits and the visits themselves will be concentrated in the month of May and June.

9. The next stage consists of consideration of the available material by the consultants, University visits, meetings with the Discipline Group, and the preparation of a draft report by September 1, 1973.

10. The draft reports will be made available to the Engineering Deans and to the Discipline Groups to provide for initial feedback to the consultants. There will be oral response from the Discipline Groups to the consultants. Following this the consultants will draft their final reports which will be followed by official responses from the above groups and finally by consideration by COU. (The above is intended to make clear that while feedback to the consultants from the Discipline Groups is desired and expected, the draft reports are not to be distributed for open discussions within departments.)

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APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

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APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

CARLETON - W.J. Rainbird

McMASTER - J.N. Siddall

OTTAWA - A.S. Krausz

QUEEN'S - P.G. Hill, until July 1, 1972
W. Rice

TORONTO - W.D. Baines

WATERLOO - E. Brundrett, until July 1, 1972
D.J. Burns

*WESTERN - E.S. Nowak

WINDSOR - W.G. Colbourne

*Chairman of Discipline Group

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APPENDIX F

ROLES OF ACAP AND OF DISCIPLINE GROUPS

Ontario Council on Graduate Studies

By-Law No. 3

A By-Law to establish a Committee on the Academic Planning of Graduate Studies.

1. The Ontario Council on Graduate Studies, recognizing the importance of providing for the continued and orderly development of graduate studies in the Ontario universities, establishes a Standing Committee to be known as the Advisory Committee on Academic Planning (abbreviation - ACAP).

Interpretation

2. In this By-Law,

   (a) "Committee" without further specification, means the Advisory Committee on Academic Planning;

   (b) "Council" or OCGS means the Ontario Council on Graduate Studies;

   (c) "Committee of Presidents" or CPUO means the Committee of Presidents of Universities of Ontario;

   (d) "university" means a provincially assisted university in Ontario;

   (e) "discipline" means any branch or combination of branches of learning so designated;

   (f) "discipline group" means a body designated as such by the Committee of Presidents of the Universities of Ontario, and normally consisting, for any one discipline, of one representative from each of the interested universities;

   (g) "planning assessment" means a formal review of current and projected graduate programmes within a discipline or a group of disciplines;

   (h) "programme" signifies all aspects of a particular graduate undertaking;

   (i) "rationalization" means the arranging of graduate programmes in order to avoid undesirable duplication, eliminate waste, and enhance and sustain quality.

Membership

3. (a) The Committee shall consist of at least seven members of the professoriate in Ontario universities, some of whom shall be members of the Council.

   (b) The members of the Committee shall serve for such periods of time as the Council may determine, and they shall be selected in such manner as may provide for reasonable balance both of academic disciplines and of universities.

   (c) The members of the Committee shall be appointed as individuals.

Chairman

4. The Chairman of the Committee shall be named by the Council, and he shall have one vote.

Quorum

5. A majority of all members of the Committee shall constitute a quorum.

Functions

6. The functions of the committee shall be

   (a) To advise OCGS on steps to be taken to implement effective provincial planning of graduate development;

   (b) To promote the rationalization of graduate studies within the universities, in cooperation with the discipline groups;

   (c) To recommend, through OCGS, to CPUO the carrying out of planning assessments of disciplines or groups of disciplines and to recommend suitable arrangements and procedures for each assessment;

   (d) To supervise the conduct of each planning assessment approved by CPUO;

   (e) To respond to requests by CPUO to have a discipline assessment conducted by proposing suitable arrangements;

   (f) To submit to CPUO the reports of the assessments together with any recommendations which the committee wishes to make. A copy of the report shall be sent to Council.

Jurisdiction

7. In order that the Committee may discharge the functions described in Section 6 above, it shall be authorized

   (a) to request a university to provide such information pertaining to graduate studies as may enable the Committee to discharge its functions;

   (b) to request a discipline group to provide such information as may enable the Committee to discharge its functions;

   (c) to receive reports from the universities and from the discipline groups, and to comment and communicate with the universities and the discipline groups concerning such reports;

   (d) to convene a meeting of any discipline group for the purpose of discussing the development to date, and proposals for the future development of graduate studies in the discipline concerned;

   (e) to send one or more representatives to a meeting of a discipline group at the invitation of the discipline group;

   (f) to make such suggestions to a discipline group as may be deemed appropriate to the functions of the Committee;

   (g) to supervise the conduct of planning assessments, and to report thereon to the Committee of Presidents of Universities of Ontario;

   (h) generally to report and to make recommendations to the Council;

   (i) to seek and receive advice from appropriate experts;

   (j) to employ consultants in connection with planning assessments;

Procedures

8. The procedure to be followed by the Committee shall be as approved by the Committee of Presidents of the Universities of Ontario.

9. The Committee's function is solely advisory.

Effective Date

10. This By-Law shall take effect January 1971.

ACAP DISCIPLINE GROUPS AND THEIR ROLES

1. Establishment of a Group

a. When it is considered desirable to activate planning of graduate work in some discipline(s) or interdisciplinary area, COU, on the advice of OCGS, will authorize the establishment of an ACAP discipline group, if it was not already approved and included in the May, 1968 list. If it is already authorized, ACAP may decide to set it up as described in paragraph b.

b. The Executive Vice-Chairman of ACAP will then invite the executive head of each university (including Waterloo Lutheran University) either to nominate a member of the discipline group or to indicate that his university has no plans for graduate study in this discipline in the next five years or so. If a university can state no plans for future graduate work in the subject, but feels that a watching brief is desirable, it may appoint an observer to the group.

c. Changes of a university's representative are to be notified by the executive head.

d. The group shall select its own chairman.

2. Meetings

a. A discipline group may meet at the call of its chairman or in accord with its own arrangements.

b. A discipline group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. The group is to keep under review the plans for graduate work in its discipline in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis.

b. The group may make recommendations to ACAP in connection with graduate work in its discipline when it considers it appropriate.

c. ACAP will assist the group in obtaining information and data, as mutually agreed.

d. When COU has instructed ACAP to conduct a planning assessment, the discipline group will assist and advise ACAP in determining procedures and terms of reference, will report as requested and will generally facilitate the assessment.

Approved by OCGS March 22, 1973
and by COU April 6, 1973.

APPENDIX G

CURRICULA VITARUM OF THE CONSULTANTS

HOWARD WILSON EMMONS

Born Morristown, New Jersey, August 30, 1912

M.E., Stevens Institute of Technology, 1933
M.S., Stevens Institute of Technology, 1935
Sc.D., Harvard, 1938
S.D., Stevens Institute of Technology, 1963

Westinghouse Electric and Manufacturing Co., Research Engineer, 1937-39
University of Pennsylvania, Assistant Professor, 1939-40
Harvard University, Assistant Professor, 1940-44
    Associate Professor, 1944-49
    Professor, 1949-

Fulbright-Guggenheim Fellow, 1952-53
Hunsaker Visiting Professor, M.I.T., 1957-58
Egerton Gold Medal, International Combustion Symposium, 1968
100th Anniversary Medal, Stevens Institute of Technology, 1970
Timoshenko Medal, American Society of Mechanical Engineering, 1971

Member, National Academy of Engineering
Member, American Physical Society
Member, National Academy of Sciences
Member, American Society of Mechanical Engineers
    Vice-President, 1967-70
Member, Combustion Institute
Associate Editor, Journal of Applied Mechanics
Member of Editorial Advisory Boards of International Journal of Engineering Sciences, International Heat Transfer Journal, and Quarterly of Applied Mathematics

Aerodynamics of combustion; supersonic aerodynamics; numerical solution of differential equations; fundamentals of gas dynamics

Address: Department of Mechanical Engineering
308 Pierce Hall
Harvard University
Cambridge, Massachusetts
02138

GEORGE FORD

Born Pocahontas, Alberta, November 19, 1919

B.Sc., Alberta, 1942
M.Sc., Alberta, 1946
Ph.D., Stanford, 1948

University of Alberta, Sessional Lecturer, 1942-46
  Assistant Professor, 1948-53
  Associate Professor, 1953-57
  Professor, 1957 -
  Head of Department, 1959-71
  Dean of Engineering, 1971-

Standard Oil of California Fellowship, 1946-48

Member, Association of Professional Engineers, Geologists and Geophysicists of Alberta, President 1963-64
Member, Engineering Institute of Canada
Member, American Society of Mechanical Engineers
Member, Canadian Society for Mechanical Engineering
Member, National Research Council, Associate Committee on Aeronautical Structures and Materials, 1955-
  Chairman, 1970-
Member, National Research Council Grant Selection Committee for Mechanical Engineering, 1967-72,
  Chairman, 1971-72

Aeronautical Engineering

Address: Faculty of Engineering
University of Alberta
Edmonton, Alberta

RICHARD DUNCAN HISCOCKS

Born Toronto, Ontario, June 4, 1914

B.A.Sc., Toronto, 1938
D.Sc., McGill University, 1971
L.L.D., McMaster University, 1971

National Research Council, Structures Laboratory, 1939-45
De Havilland Aircraft of Canada, Ltd., Chief Engineer, 1945-69
National Research Council, Vice-President (Scientific), 1969-
Canadian Patents and Development Ltd., President, 1970-

Order of the British Empire, 1945

Fellow, Canadian Aeronautics and Space Institute
    Past President
Fellow, Royal Aeronautical Society
Fellow, Engineering Institute of Canada
Member, Ontario Engineering Advisory Council
Member, Advisory Council of the Ryerson Polytechnical Institute

Address: National Research Council
Division of Administration
Building M58
Montreal Road
Ottawa, K1A 0R6

STANLEY GEORGE MASON

Born Montreal, Quebec, March 20, 1914

B. Eng., McGill, 1936
Ph.D., McGill, 1939

Trinity College, Lecturer, 1939-41
Department of National Defence, Suffield Experimental Station, Alberta,
    Senior Scientist and Department Head, 1941-45
National Research Council, Atomic Energy Division, Associate Research
    Chemist, 1945-46
Pulp and Paper Research Institute, Director, Applied Chemistry Division and
    Head, Physical Chemistry Section, 1946-
McGill University, Research Associate, 1946-66;
    Professor, 1966-

Fellow of the Royal Society of Canada
Fellow of the Chemical Institute of Canada
Kendall Company Award in Colloid Chemistry, American Chemical Society, 1967
Bingham Medal, Society of Rheology (U.S.A.), 1969
Anselme Payen Award in Cellulose Chemistry, American Chemical Society, 1969
Chemical Institute of Canada Medal, 1973

Member, Chemical Institute of Canada
Member, American Chemical Society
Member, British Society of Rheology
Member, Society of Rheology (U.S.A.)
Member, International Society of Biorheology

Rheology and stability of disperse systems; physical chemistry of polymer solutions; transition phenomena in critical region; chemistry of pulp and paper; haemodynamics

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McGill University
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Montreal 101
Quebec

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APPENDIX H

RESPONSE OF THE COMMITTEE OF ONTARIO DEANS OF ENGINEERING

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COMMITTEE OF ONTARIO DEANS OF ENGINEERING

RESPONSE TO ENGINEERING PhD ASSESSMENTS

Preamble

Individual reports of PhD Assessments have already been received by discipline groups and by individual universities. Both bodies will undoubtedly make detailed commentary on the specific reports which are of direct concern or interest. In view of this, CODE has decided to forego comment on such specifics, and has determined to refer only to those matters of a more general nature which affect the universities collectively. In choosing to frame its response in unitary fashion, CODE wishes, at the outset, to emphasize that it views engineering education and practice as a total activity instead of a discrete set of unrelated disciplines such as Chemical, Civil, Electrical, Materials, Mechanical and Metallurgy, etc. This theme of relationships between disciplines within a faculty, and indeed between faculties, will recur later in the report in subsequent discussions.

Of the ten topics on which CODE sets out its 'responses', three are considered to be of primary importance - manpower, quality, and critical size. Consequently, they have been covered in somewhat greater detail than have other topics of interest, in order to provide identification and emphasis, rather than a fully developed 'position'.

The primary concern in this response is unquestionably that of quality over quantity. In assuming this position CODE realizes that the indicators of quality are undoubtedly staff, students, programmes and facilities. It is difficult to assess the precise hierarchy of these four basic parameters. Suffice it to say that, while the first two are paramount in terms of establishing potential for excellence, the last two are important in realizing this excellence.

CODE offers its resources in such further and subsequent amplification as may be useful to the purposes of the Council of Ontario Universities.

Manpower

CODE is in agreement with the general observations of the consultants with respect to the PhD manpower situation. It appears clear that the supply of PhD candidates will be limited by the availability of high quality entrants. The relatively small numbers of Canadian graduates entering PhD programmes is a cause for concern. If Canada is to advance industrially, it would be expected that there would be an increasing demand for high-technology support. An under-supply of PhD graduates in engineering would not be in the best interest of society. There is clearly no evidence of any over-supply because of the way engineering graduates at all levels are seen to diffuse widely through industry, commerce and government; there appears no prospect of this becoming a problem in the future.

CODE realizes the importance of maintaining up-to-date knowledge of positions taken by the PhD graduates of the Ontario Engineering schools and intends to ensure that such information is updated annually. A copy of a recent survey is included as part of this response. It will be noted from this survey that there has been a shift in the area of employment of engineering PhD's towards industry.

In the light of the consultants' analyses, and of the appended data, there is no need for quotas or ceilings on doctoral students. CODE will continue to report on the number and origins of doctoral students in the various engineering schools, on an annual basis.

Quality Emphasis

(a) Admission

CODE is pleased to note that the consultants have agreed that high admission standards to engineering doctoral programmes generally prevail.

CODE, therefore, supports the contention that existing minimum entrance standards to PhD programmes should be maintained across the Province. CODE believes that a post facto analysis of admission practices, widely publicized, will be adequate to ensure this objective.

In application of these standards, it must also be acknowledged that certain defensible exceptions will occur with respect to those with known special abilities or those who have demonstrated superior ability in research, design and innovation in their post-baccalaureate experience.

CODE fully supports the view of the electrical consultants that it is "in Canada's interest, especially in international competition, to have strength in high-technology research and development" and for this to happen there must be an objective of "high standards of excellence with emphasis on quality".

(b) Programmes and Faculty Facilities

CODE recommends that totally independent and representative bodies continue to oversee negotiated development grants and the formation of centres of excellence. These are matters better left outside the jurisdiction of such a body as CODE.

(c) Undergraduate/Graduate Programme Relationship

CODE supports the contention that the continued existence of a live, up-to-date undergraduate programme requires the backing of a good

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research programme and participation in professional practice by members of the faculty. The research activity, in the prevailing tradition, is most easily met through the provision of Master's and PhD postgraduate programmes.

(d) Quality Indicators

In addition to the observance of university regulations, and the use of high calibre external examiners, the observed career performance of doctoral graduates can be used as a 'quality indicator'.

Critical Size for Doctoral Programmes

In order to be viable, a PhD programme must provide a sufficient range of interaction for the student. He must be exposed to enough faculty members and enough other students to provide adequate breadth of experience and instruction. The adequacy of this breadth cannot be judged exclusively by the size of the department in which he is registered.

The ACAP assessments, by being completely vertical, miss the rich horizontal components which can and do nourish and sustain viable doctoral programmes in both small and large departments and faculties. Resources from other divisions of the university, other engineering departments, industry and, indeed, other engineering faculties must be considered in any realistic analysis of PhD programme viability.

Size is not a sufficient criterion for judging whether a school can offer a PhD programme; there is no *a priori* reason why a small school cannot provide as satisfactory an environment for the student as can a large school.

Engineering in the Wider Context

CODE would draw attention to the need to view the totality of the PhD programmes in engineering not just in isolation, but also in the context of other related disciplines; e.g. physical, life and social sciences.

To progress technologically in such a way as to improve the quality of life not only in Canada but also in other parts of the world, it is essential that there be work proceeding concurrently in the forefront of various other disciplines which impact on engineering. It is anticipated that increasingly advanced work in various areas will need to proceed in a more integrated fashion and it will be essential to have available high level manpower in the physical, life and social sciences, economics, and management, for instance, together with similar capabilities in engineering.

Research Emphasis and Relevance

As a result of the ACAP Engineering Assessments, there is now readily available information about research projects underway in all the Ontario

Engineering Schools. The system would have profited more had the consultants commented in detail on this information and offered substantiated specific advice on the topics of emphasis and relevance.

CODE feels that PhD programmes in engineering should be flexible enough to cover a broad range of topics. Research activities could and should range from mission-oriented research of an immediate and perceived social or industrial relevance through to very fundamental or basic research. The overall thrust of PhD research programmes should be towards advancing fundamental engineering knowledge required for the solution of present and future engineering problems.

CODE also feels that a plurality of sources of research support is a relatively effective means of ensuring that a broad spectrum of research activity is undertaken within the engineering schools. The existence of a variety of granting bodies, with a spectrum of interests represented, including a significant academic component, appears to be an effective method of control.

Level of Support for Doctoral Students

CODE strongly supports the contention that levels of support for doctoral students must be increased substantially if more Canadian students are to be attracted to entering doctoral programmes in engineering.

It should be noted that foreign graduate students have been willing to undertake PhD studies at the levels of support available and have subsequently filled positions within Canada. Positions have been available for PhD's - these have been filled largely by landed immigrants who have either completed PhD study in Canada or who have come to Canada with a PhD.

The recent increases in both the cost of living and salaries offered by industry to engineering graduates makes it even more urgent that immediate action be taken to increase the support for doctoral students. This is particularly true if post-baccalaureate experience students are to be attracted. Therefore, it is important that more opportunities be available for this particular type of doctoral student in engineering.

Part-Time/Non-Resident Work

CODE would encourage continued experimentation in this regard. It is felt that maintenance of some institutional contact is essential, however. It is felt further that any part-time or non-resident work should normally be by individual arrangement. This would not, of course, preclude special arrangements between a research institution or industry/government laboratories and a particular university or universities.

Inter-University Activities and Facilitating Mechanisms

CODE would support any action designed to increase the effectiveness of the provincial resources in faculties of engineering. The holding of discipline meetings, the sharing of equipment, interchange of credits for graduate courses, collaboration between groups within various institutions and so on are to be encouraged. It is emphasized that co-operation often involves travel and other expenses that are not always readily available in individual schools and that this matter is worthy of further investigation.

It is noted that inter-university activity is proceeding especially at the 'grass-roots' level and this can be aided and abetted by CODE. It is also noted that various university industrial research institutes and similar agencies have facilitated some inter-university cooperation largely through use of individual expertise existing at various institutions.

The Role of the PhD in Entrepreneurship

CODE feels that entrepreneurial activity by PhD's is something which cannot be legislated. However, it feels further that the PhD has, by virtue of his total background, significantly greater potential for success in such activity than has the member of the general populace. It suggests that there are two avenues of encouragement which can lead PhD's in greater numbers into entrepreneurship. The first depends on the educational institution itself, which must, by appropriate orientation and emphasis, develop an interest in or leaning towards innovation, independent practice, or entrepreneurship. The second depends on progressive government support programmes of various kinds, directed to reaching a 'climate' competitive with that found in other industrial economies of comparable size.

Cost-Benefit of the ACAP Studies

CODE has noted that no major measures are proposed that would greatly enhance the quality of the PhD effort in Ontario. Indeed, CODE records its pleasure at the broad and independent affirmation of the consultants as to the strengths and qualities which have developed in Ontario PhD programmes.

The full programme of ACAP studies is as yet incomplete. CODE has yet to be convinced that the extensive funds and efforts devoted to the studies would not have been better spent in direct support of existing PhD programmes in engineering.

ANS/dd
December 27, 1973

APPENDIX A

REPORT ON THE CODE ENGINEERING DOCTORATE EMPLOYMENT SITUATION, OCTOBER 1973

In November 1973, members of the Committee of Deans of Engineering of the Province of Ontario again supplied data on the status of their engineering PhD graduates during the period November 1972 until October 1973. The results are compared in Table 1 with those for 1972.

Again this year, the majority of the graduates were in Chemical, Civil, Electrical and Mechanical Engineering. The total is up substantially to 177 from 124 in 1972.

Unemployment is up from one in 1972 to three in 1973 (approximately 1.7% of the total).

Approximately 17% have left Canada, which is the same as for previous years and is probably due to the return of foreign students to their home countries.

A notable increase in employment in industry has occurred, up to 33% from 21% in 1972. The number employed in Canadian universities is up to 26% from 21% in 1972. This has been accompanied by a decrease in post-doctoral fellowships from 23% to 11%.

The overall conclusion is that there is still no serious unemployment among recent Ontario PhD graduates in Engineering despite predictions to the contrary. In fact, a healthy trend toward their increased utilization in Canadian Industry may have been established.

December 13, 1973.

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ONTARIO ENGINEERING PH.D EMPLOYMENT SURVEY 1973

The employment status of one hundred and ninety-two graduates with PhDs in engineering from Ontario universities during the period November 72 to October 73 was determined in November 1973.

ENGINEERING DEPARTMENT OR DISCIPLINE	Unemployed		No professional Employment		Employed in Industry		Employed in Government		Employed in Universities		Postdoctoral Fellowships		Have left Canada		Unknown		TOTALS	
	1972	1973	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
Aero/Space	-	-	-	-	1	3	-	-	1	3	4	1	-	-	-	-	6	7
Bio-Medical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Chemical	-	1	-	-	4	13	1	3	7	5	7	5	3	2	4	2	26	31
Civil	-	1	-	-	5	7	2	5	3	14	6	5	9	7	5	-	30	39
Electrical	-	-	2	-	9	20	3	2	5	11	7	5	4	9	1	-	31	47
Industrial	-	-	-	-	2	-	1	-	2	-	-	-	-	-	-	-	5	0
Materials/Metals	-	1	-	-	1	6	1	-	1	3	2	2	-	3	-	-	5	15
Management	-	-	-	1	-	-	-	-	1	1	-	-	-	1	-	-	1	3
Mechanical	1	-	-	-	4	9	2	5	6	8	1	1	2	7	2	1	18	31
Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Physics/Science	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2	0
Systems Design	-	-	-	-	-	-	-	1	-	1	-	-	-	2	-	1	0	4
TOTALS	1	3	2	1	26	58	10	16	26	46	28	19	19	31	12	4	124	177

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APPENDIX B

Comments on CEMC Report

"Supply and Demand for Engineering Doctorates in Canada" (July 1973)

Submitted by the Committee of Ontario Deans of Engineering

Commendation of this report can be made in a general sense on two main scores. Firstly, the consultants have, on assignment, tackled in a straightforward manner, what is generally acknowledged to be a most difficult task indeed; where qualitatively it is not possible to assert all possible parameters, and quantitatively, it is not possible to obtain reliable data on all accepted parameters.

Secondly, the consultants have in their report introduced with some care statements relating to the qualifications and limitations of the many elements entering into their predictions, and have emphasized that this is only a beginning - ergo, a very preliminary report.

Within this general context, however, there are a number of criticisms to be advanced.

1. Supply

The methodology has been clearly enunciated, and the assumptions stated. Nonetheless, projections have been made on a three-level approach (high, medium and low), establishing bounds which may well be broken as and when certain assumptions become less or more operative. Some indicators are already present as to the dangers of some of the assumptions.

1.1 Admission requirements are not static, and are increasingly adaptable to the changes in the high school. Three other important aspects must be added. There is, firstly, foundation for expecting a major growth in the number of women entering engineering. Secondly, the "market-place" reaction with a rapid response in the 1st year enrolment to a proclaimed shortage in engineers will continue to be operative. Thirdly, there is further indication that advanced admissions (through the stop-outs returning, through technology graduates admissions, etc.) are increasingly important in enrolment projections. None of these has been clearly taken into account in this report. A further aspect could well be added, which is also ignored in the report, but is less easy to define though it will contribute to the instability in prediction of 1st year enrolment. This relates to measuring the full impact of major educational changes on the Canadian scene. The effect of the CEGEP's in Quebec in particular, as well as of the CAAT's in Ontario, is yet to be clearly perceived, let alone settled into a measurable or stable influence.

1.2 The two data bases selected for examination were the number of master's degrees and the number of baccalaureates. The discarding of the master's degrees/doctorate degrees ratio as credible seems to ignore the very recent development of many doctorate programmes as contributing to a rapid change in this ratio. The total postgraduate effort in engineering in Canada is of such an emerging character that rates of change must be evaluated much more carefully. This is equally true for the baccalaureate/doctoral ratio selected as a data base. The evidence for stabilization in this is slight, and even the selection of three ratio levels is likely subject to major error through neglect of variable factors in an easily perturbed system. The changing pattern in the number of Canadian baccalaureates who earn doctorates outside the country is one further feature of a system which as yet has little maturity or stability in it. This aspect of immigration was noted in the resport as one for which no data was available - which ignores one fully-documented part of the system, the Athlone Fellows.

1.3 The utilization of the baccalaureate/doctoral ratio as a data base for predicting future supply has another feature which is inadequately considered and analysed. This relates to the forces which are operative on graduates of Canadian engineering schools vis-a-vis their proceeding to doctoral work. Graduates of the engineering schools of Canadian universities have never come forward in substantial numbers to undertake advanced study and research. The tradition of such a choice, and indeed the number of opportunities for such advanced work, are relatively new on the Canadian scene. The expansion of the graduate schools over the past decade has been effected therefore by the attracting of students with overseas degrees, particularly from Asia. Many of these students from overseas have been or have become landed immigrants, have stayed in Canada and have taken jobs as PhD's. These jobs have been available, they have not been taken up by Canadians who seem to have preferred to enter the work-force earlier, immediately after obtaining the bachelor degree. There are probably many factors which have conditioned the particular choices of Canadian engineering graduates at the bachelor level, but primarily it is probably a combination of (a) the fact that they have been so readily absorbed into the economy at that level, and (b) the fact that the level of financial support available for graduate study has been too low to make them feel that the sacrifice is worth it. For the near future, unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline. At the same time as the graduate schools in engineering become increasingly well established and recognized, and as high technology factors including its encouragement through government policies increasingly become operative, the opposite effect could well occur. The imprecision therefore in assuming a stabilized bachelor/doctoral ratio is greater than assumed in the CEMC study.

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1.4 In the consideration of the report, moreover, one should not perhaps overlook the possible impact of events occurring in other jurisdictions. The report suggests that the annual number of bachelor degree graduates will fall from about 4,500 to 3,000 over the next three years, with most of this decrease due to a falling-off in freshmen enrolments in provinces other than Ontario. This could suggest in itself a likelihood of fewer qualified Canadian graduates available for PhD studies at our universities. This must be viewed in conjunction with the situation in the U.S. where undergraduate enrolments in engineering have fallen very sharply over the last few years and this will lead to a very substantial decrease in the number of bachelor engineering degree graduates over the next few years. The combined Canada/U.S. graduating class was about 47,000 in 1971. It will be only about 35,000 in 1975. One might wonder whether, because of excellent opportunities at the bachelor level, a smaller proportion might proceed to PhD work or conversely whether the lack of anxiety about employment prospects at the bachelor level will give more students the confidence to continue with their studies.

1.5 A further major criticism of this part of the report rests not on the methodology, elements of which have been discussed above, but on the basic data used in the calculation steps. Without examination of each and every set of data used, it can nonetheless be indicated that the rather complex combinations of undergraduate enrolment and graduation data from Statistics Canada, from EIC enumerations, from the "Ring of Iron" for Ontario leave some inconsistencies. The number of bachelor's graduations and of doctorates were obtained only to 1970-71, while the number of master's degrees were recorded for 1971-72. In view of the rapid build-up in Canada of doctorate degrees (from 78 in 1965-66 to 216 in 1970-71) it would have seemed to be quite important to establish the 1971-72 figures before final projections were carried out. In view of the prominent place taken by the Ontario system contribution it is indeed surprising that more current data at hand in COU (ACAP) was not utilized. Nonetheless, it is fair to point out that the actual doctorates in Ontario for 1972 and 1973 respectively were 124 and 177, and that the former figure compares to the low level projection for 1971-72 of 126, and the latter to the high level projection of 172 for 1972-73. At least the projection band width used just encompasses the first stages of comparative actual data.

2. Demand

The report includes a comprehensive survey of manpower demand methods, and a careful statement of the method followed for each of the sectors explored, as well as its limitations. This demand aspect of the report is the one which has received the most criticism from the ACAP consultants in the five engineering fields assessed. Our criticisms encompass the major elements of those comments in summary form as well as those voiced by the engineering schools in Ontario.

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2.1 Educational Sector

The consultants' use of a model for the estimation of future demand in the educational sector is deceptively attractive. Essentially, their model was based on a staff-student ratio as a base, adjusted for retirement, mortality and migration. They concluded that to 1977-78 (at least) the demand for engineering doctorates would be essentially zero, and then admitted "this will not prove to be an accurate scenario". They then rest their case that in both universities and other educational institutions, the demand will be "minimal". In the dictionary sense of the least attainable or extremely minute in size, it is difficult to read into this other than essentially no demand. Even though rather elegantly derived, we find it hard to accept such a conclusion, particularly when the Ontario system itself projects now a demand for about 20 for 1974. Some of the parameters which would be omitted by the model used include increased demand through major block research grants, through mission-oriented research, and through the development of new programmes and areas. The report does deal at length with the question of "substitutability between inputs", but does not weigh it to the level where it would not be balanced by other factors. This question of substitution will also be referred to below in considering the total demand-supply picture.

2.2 Government and Industry Sectors

In these sectors the consultants chose to establish stock data and forecast demand for 1974, 1975 and 1978 by direct survey. From the many criticisms and indeed specific refutations that can be made, it is clear that this survey has been far too narrowly cast. In the government area this is certainly true regarding the narrowness of definition used. In the industry area it includes not only that limiting factor, but became subject to both incomplete data through using wrong sources, and through important omissions. To some degree the consultants were well aware of these deficiencies, but were obviously more conscious of them for the forecast demand data than for the stock data - where equally gross errors and omissions seem to have occurred. One example of such an error is in the stock of 52 in 1973 attributed to AECL, compared to the 90 actual in 1973 as provided by the Metallurgical engineering consultants in their report to ACAP. Other reports to ACAP specify other examples.

It is hard to escape the conclusion that the inadequacies of the demand survey are far greater than the consultants envisioned, and their errors of omission are much greater than they estimated.

3. General

3.1 Educational Planning and Manpower

What appears to be a basic premise of the report as contained in paragraph 1 on page (1) deserves comment, viz.,

> "Now, a generally accepted view is that the expected labour market for graduates of a particular speciality should influence policy and planning in post-secondary education in that area."

This view may not be as generally accepted as one might be led to believe. The particular philosophy outlined can, taken to extremes, result in a shortsighted and constrained view of a university. It could well be argued that too marked a distinction has been drawn between what is educational and what is vocational. Recently this has been convincingly stated to be one of the major misconceptions in higher education planning*. The danger in assuming that all but preparation of people for specific jobs is wrong or wasteful is not just in the short-sighted effort to establish a one-to-one relationship between education and jobs. Rather it omits the important fact that vocationally oriented education is not wasted if it is not used in the specific vocation toward which it was directed. As Bowen* states, "It is no mark of failure, rather a mark of success, that education - even strictly vocational education - has wide applicability and produces flexible and versatile people". The PhD graduate even if he takes a vocational route initially may well very soon find himself in positions where his PhD can be regarded only as part of his general education or as a contributing factor to his intellectual development or problem-solving ability. It is not difficult to give examples of this "diffusion" of PhD's through a "vocational" period to positions of quite different responsibilities in industry, governments and the universities. The consultants gave careful attention at one stage in their report to this "diffusion" or dispersion, referring properly to the recent University of Toronto study. However, they did not then "factor" it in to either their supply or their demand projections. In our view, significant allowance should be made for it. On the supply side, both into the baccalaureate stream as well as into the doctoral stream in engineering the vocational/educational issue is not clear-cut nor should it be. On the demand side, there must be allowance made both for the substitutability through flexibility even at initial employment levels, and for increasing mobility and transfer into wider areas such as management as experience accrues. The difficulty of quantifying this is well appreciated. The need for including it in some definitive way demands equal appreciation.

3.2 The Supply and Demand Balance

The report in its final results and conclusions comes down strongly on the prediction of an oversupply of engineering PhD's in the decade ahead. They acknowledge a range of factors which will influence both their supply band projection and their demand band projection, including the possible effect of their own report. We acknowledge this danger and can only hope that it can be minimized by vigorous emphasis both on the limitations of the report's projections but also on the countering evidence as it accumulates. We have indicated some of the aspects of both the supply and the demand projections which can invalidate the narrowness of the band widths selected. Perhaps more importantly in the long run is the real failure of any demand projection to be able to take into account any but the very short-term skill requirements of the economy. The evidence is quite clear that our society has an enormous amount of work to be done with a lack of sufficient skilled manpower to do it. We would claim that the adaptability of doctoral graduates in general combined with the adaptability of our economy results in a surprisingly good balance. The Ontario experience, well documented now for four years, indicates essentially no unemployment of engineering doctorates, no unusual hold-up or storage in a post-doctoral form, and changing flows into government and industry as demand from the universities slacken. The acceptance of a current balance, which does exist (with some evidence indeed of unfilled needs in some areas), could well be the starting point for the report's projections. The graphical summary given on page 18 would then present an entirely different picture.

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* H. R. Bowen, "The manpower vs. the free-choice principle", University Affairs, Jan. 1974.

We should rise above our national tendency to be cautious and pessimistic, recognize that even a PhD may be viewed as vocational or educational (hopefully both) according to the graduates perception of the market-place, alternative opportunities, his own desires and so on, and not deliberately cut back on PhD enrolments in engineering, especially on demand data of such doubtful validity as that contained in the CEMC preliminary report. We have so little to gain and so much to lose by taking such an approach. We need to display more optimism and confidence in ourselves and in the ability of highly educated manpower to seek out and create opportunities and to raise the level of some existing positions both in government and industry. It is to be hoped that our students also will display such optimism and take a broader view of the value of their education, and that this view is shared by our federal and provincial governments. We will need this spirit if we are to move into an era in Canadian industry where increasing sophistication and high technology become more and more necessary.

NOTES

Re: 1.1

Entrance to engineering was assumed constant on a demographic base, i.e. 0.5% of male population age 15 to 19; and assumed unchanged entrance requirements.

Re: 1.2 and 1.3

The greatest danger in assuming the validity of a stable B/D ratio for projection purposes resides in the fact that the doctorate figure for the last decade includes a very large but unknown number who did not come through the Canadian baccalaureate stream. The size of that group of doctorates was related largely to immigration policies (now changed and changing), to research grants policies (which have also changed), and possibly to more selective admission policies. Perhaps a meaningful B/D ratio could usefully be established when the D number arises almost entirely from the B stream. Such data have not been collected.